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UNIVERSITY OF ALBERTA  
APPLICATION OF METHODS ENGINEERING  
IN IRRIGATION

by  
TOFIGH V. MUSSIVAND

A THESIS  
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UNIVERSITY OF ALBERTA  
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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Application of Methods Engineering in Irrigation" submitted by Tofigh V. Mussivand in partial fulfilment of the requirements for the degree of Master of Science.



## ABSTRACT

It is believed that the provision of facilities to establish a series of standard time values for various elements and jobs in irrigation methods has never been attempted before. In this study not only have S.T.V.\* for the different tasks in irrigation methods been obtained and listed in Appendix A, but many improvements were also developed. The studies led to the following developments.

1. A catalogue of S.T.V. for each irrigation operation has been prepared.
2. The labour-hours required per acre, per irrigation for commonly used irrigation methods have been calculated.
3. The relationships between the factors affecting the cost of labour have been found. They include the effects of the length of pipe, number of pipes carried each time, number of operators, and crop height, soil, moisture and muddiness, and wind.
4. A series of empirical formulae have been developed for the calculation of the required labour hours and cost and hence the selection of the best irrigation method, providing other factors are kept the same.
5. A method of moving lateral pipes has been developed which saves 15.83 per cent of labour cost for moving the sets in hand move sprinkler systems.

\*Note: S.T.V. = Standard Time Value. For definition refer to Part II.  
2.3.9 p. 35



6. A method for setting up the pipes which saves 70 per cent of labour and time to lay out the pipes, has also been developed.
7. The possibility of use of an automatic end-plug for sprinkler systems have been demonstrated as having a potential labour saving of 28 per cent over present methods of cleaning the pipes.
8. An automatic drainage valve for draining the pipes in sprinkler systems has been designed which saves 25 per cent of labour cost.
9. It has been determined that with the proposed new methods, two men teams are preferable in almost all circumstances to one man working alone; although under the present equipment design and present methods, a single operator is often the cheaper.
10. Many of the existing methods include motions and activities which can be eliminated to reduce the time needed to accomplish the same tasks.

It is hoped that the table of S.T.V. and other results will be useful to compare irrigation methods labour cost and final selections and practices.



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## PART I

### INTRODUCTION AND OBJECTIVES

The field of methods engineering and its application in irrigation includes designing, creating, and selecting the best irrigation methods, processes, tools, and equipment used in irrigation. This is achieved by careful analysis of work study techniques, including the determination of the time required by each system and method of irrigation, for a given unit area. Subsequently, the predetermined time standards are tested for validity. The product of this thesis is the determination of factors giving the most economical ways of irrigation, including the consideration of the present methods and special conditions existing in the area to be irrigated.

Early in the course of study it was noticed that the labour cost is one of the irrigators' major annual expenses. It is estimated in Appendix F that in each season in Alberta alone, about three million dollars are spent on labour for irrigation. This lends considerable practical benefit to the objectives of this thesis. These are:

1. Determination of a series of standard time values for operations in irrigation methods.
2. Development of better methods of labour utilization; by the consideration of irrigation techniques stressing economic and human factors.



3. Improvement in the design of the equipment used for irrigation processes.
4. Provision of a simple means of identifying the best method of irrigation, in terms of labour saving and cost for any specified situation.

The above four major objectives were formulated during the field studies, but there are still many obscure and hidden factors to identify and quantify, that will need many more years of research to clear and lighten.



## PART II

### LITERATURE REVIEW

Irrigation undertakings are a combination of both engineering and agricultural personnel, resource and research establishments where controlled water supplies are applied to lands in order to produce crops.

For many thousands of years mankind has tried to use his knowledge and skill for the betterment of irrigation practices. Civilizations began with irrigation and ended when mal-practiced methods of irrigation were introduced.

Since irrigation is of prime importance to man, the development of its techniques was undoubtedly among the earlier human sciences or arts. Ancient Egyptians, Babylonians and Persians were using their science in irrigation as early as 2500 B.C. Astronomy, mathematics, law and economics were used in the field of irrigation. Nimrod, mentioned in the Bible, and Koran as the founder of Nineveh and the first king of Babylon wrote laws and manuscripts for irrigation. Indians, Assyrians, Greeks and Roman scientists and engineers such as Archimedes, Vitruvius and Frontinus have written books about water and irrigation.

After the Romans and Islamic nations progressed, many others such as Gallileo, Torricelli, Henri Pitot, Daniel, Bernoulli, Leneounard Euler, Darcy, Froude and many others published books and developed principles and equations for hydraulics and water usage.



At the present time there are many books, pamphlets, and brochures written about irrigation. Because of the objectives of this thesis, it was unavoidable to not refer to any principle of irrigation and methods engineering. Therefore, the following related topics have been adopted from various books and publications.

2 - 1. Methods of Irrigation

2 - 2. Methods Engineering

2 - 3. Time Study

In the Bibliography, the headings of references used are:

I - Hydraulic Engineering

II - Irrigation

III - Work Study



## 2.1. METHODS OF IRRIGATION

When uncontrolled streams of water are turned into fields, waste, inefficiency, and uneven distribution are almost certain to result; this is undesirable. The following are among the most common methods of irrigation of which some, but not all, are practical in southern Alberta. These are divided into two categories.

1. Surface.
2. Sprinkler.

### 2.1.1. Surface Irrigation Methods.

#### 2.1.1.1. Furrows.

Furrows are most commonly used for row crops such as potatoes, corn, vegetables, cotton, sugar beets. They are ordinarily made during the process of cultivation. A furrow four inches wide and four inches deep is normally used. Furrows often run directly down the slope, but to control erosion they should run on the contour. The length of furrows varies from 150 to 1320 feet according to slope and soil.<sup>1</sup>

#### 2.1.1.2. Corrugations.

Corrugations are shallow furrows running down from head ditches and are used for alfalfa, grains, and pasture. This method is generally used on fine textured soils that take water slowly and on

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<sup>1</sup>Paul H. Berg, Proceedings of the American Society of Civil Engineers, Journal of the Irrigation & Drainage Division, Volume 86-No. IR3, Part 1, Ann Arbor, Michigan, U.S.A., September 1960., p. 78.



land that is moderately steep or irregular. Corrugations are generally two inches to three inches deep and are spaced from 14 inches to 36 inches apart. The streams vary from one to five gpm depending on slope and soils. The length of run should be the same as furrows.

#### 2.1.1.3. Borders.

Borders consist of dividing the field into a number of strips separated by low flat dikes running in the direction of greatest slope, preferable at a uniform grade. The dikes are about three feet wide and one foot high. Strips may vary from 20 feet to 66 feet in width and from 200 feet to 1500 feet in length, depending on the stream, intake rate of soil, slope of land. Any slope in excess of three percent is undesirable.

#### 2.1.1.4. Basins.

Basins consist of large streams which run into level plots surrounded by dikes. They are used on fine textured soils, where the intake rate is low, and it is necessary to hold water on the surface to secure adequate penetration. Most crops can be irrigated by this method.

#### 2.1.1.5. Flooding.

This is mostly used for pasture. Field laterals are constructed on the contour having a grade of not more than 0.1 foot per 100 feet. Water is diverted from the field lateral and allowed to flow, uncontrolled over the land. Field laterals are usually close enough together to collect the runoff water, before it is allowed to concentrate in a swale, and then the water that is collected in the lower laterals is redistributed over the next lower field.<sup>2</sup>

---

<sup>2</sup>Ibid, p.80.



### 2.1.2. Sprinkler Systems

The spectrum of sprinkler systems can be subdivided into two groups.

1. Hand Move.
2. Mechanical Move.

Both are found in Alberta.

#### 2.1.2.1. Hand Move

In this type pipes and sprinklers are moved by hand between locations (sets). The available systems of hand move are:

##### 2.1.2.1.1. Low pressure hand move.

This is used for gardens, small plots, orchards. (Low Pressure with pipes are two inches in diameter.)

##### 2.1.2.1.2. Medium pressure hand move.

This is the most commonly used method in Southern Alberta. It consists of moving lateral pipes with sprinklers at 20, 30 and 40 feet intervals, with a pressure of about 40 psi at the sprinkler farthest from the pump, each sprinkler having a discharge of 6 to 15 gpm. The lateral pipe will operate for a period of three to twelve hours at each set (location); then, it is uncoupled and moved to another set, it is generally sixty feet in the Lethbridge area between sets.

##### 2.1.2.1.3. High pressure and high volumes.

This consists of one or two large sprinkler nozzles with discharges of from 300 to 600 gpm at 80 to 100 psi. The pipes and sprinklers are moved from 200 to 300 feet per set.



#### 2.1.2.2. Mechanical move.

These types of sprinkler systems are moved by some mechanical device such as wheels or skids.

##### 2.1.2.2.1. Wheel move.

Here the lateral lines are mounted on wheels and the lines are moved by the power supplied by a small air-cooled engine mounted in the middle of the lines.

##### 2.1.2.2.2. Valley system.

The lateral line is mounted on large "A" frame units and pivots around an anchor in the center of a quarter section, acting on a piston type mechanism and each unit provides the power to propel it around the central pivot. In this method 18 per cent of the total area will not be irrigated, in any square area, in which the circular system of radius  $R$  is inscribed.

### 2.1.3. Components of Sprinkler Systems

Regardless of the type of system the following items comprise a complete irrigation system.

#### 2.1.3.1. Power unit.

This may be gasoline, diesel or propane or electric motor, or a farm tractor using power take-off.

#### 2.1.3.2. Pump.

Various sizes for the different systems are used. Mostly centrifugal types of pumps are used in Alberta.



#### 2.1.3.3. Main and Lateral pipes.

The pipe has a diameter from two inches to eight inches, and comes in lengths of 40 feet or more. It may be aluminum or plastic or some kind of rubber. Four inch diameter pipe is the most commonly used size for laterals.

#### 2.1.3.4. Fittings.

These are tees (T), reducers, elbows, tee valves, valve openers, risers, end-plugs, and couplers which may be of a "quick-detachable" type.

#### 2.1.3.5. Rotating Sprinklers.

These vary between differing crop and soil conditions.

#### 2.1.3.6. Suction hose and suction intake pipes.

Hoses are used to provide flexibility and dampen the vibration.

#### 2.1.3.7. Suction strainer to prevent plugging.

#### 2.1.3.8. Discharge Check Valve.

These are used to close discharge of pump when priming, or to protect the pump from back pressure caused by any failure in the system.

#### 2.1.3.9. Primer.

To remove air from pump and suction line when priming the pump.

#### 2.1.3.10. Safety Controls.

These are connected to driving unit control and pump to protect them from overheating, oil and pump, or other kinds of failures.



#### 2.1.4. Factors Influencing the Selection of Irrigation Methods

There are five major factors which influence the selection of a method of applying irrigation water.<sup>3</sup>

1. Precipitation.
2. Intake rate and capacity for available water in the soil
3. Topographic relief and soils.
4. Crop to be irrigated.
5. Cost of applying water.

The method of irrigation chosen should always be the best for a certain factor or combination of these factors dependent upon their relative importance.

##### 2.1.4.1. Precipitation.

This is an important factor because it controls the number of sets per year, since the precipitation will be used by a crop if it comes during the growing season. Alberta is in the rain shadow of the Rocky Mountains and is, therefore, relatively dry; although there are some useful summer rain-fall. These come in the form of heavy showers, and there is a band of fairly heavy precipitation on a southwest to north-west line from south of the Peace River Region across Swan Hills, the Pelican Mountains and eastward.<sup>4</sup>

The average annual precipitation in the area in which this research was done varies from 13-inches to 16-inches (Medicine Hat, Lethbridge, Taber, Bow Island.) The precipitation in 1966 was much higher and in some areas was enough to eliminate the need to irrigate on several occasions.

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<sup>3</sup> Ibid, p.79.

<sup>4</sup> Alberta Farm Guide 1963, Canada and Alberta Departments of Agriculture, Distributed by Extension Service, University of Alberta, Edmonton, Alberta, p. 26.



#### 2.1.4.2. Intake rate.

This is the rate at which water moves into the soil. Generally in North America it is measured in inches of water per hour. This factor has a great influence on determining the method of irrigation and frequency of applying water. If the intake rate is high, it may be virtually impossible to apply water by surface methods because the required flow of water would be large. Conversely, if the intake rate is very low the application of irrigation water needs to be in such small quantities that it must be almost continuous to meet the plant requirements.<sup>5</sup>

Available water in soil is the relative volume of water in the soil which is readily available for plant use in the root zone. Measurement is usually made in inches of water per foot of soil depth; it is inversely proportional to the size of soil particles. This factor controls both the method and the frequency of irrigation. Sandy soils hold little available water because of the larger voids and rapid percolation of water below the root zone of plants. The available water varies inversely as the intake rate.

The sandy soils would require frequent light applications of water and the clay soils would require infrequent heavy application of water. The length of time required for each irrigation of clay soils would be much greater than for the sandy soils.<sup>6</sup>

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<sup>5</sup>Paul H. Berg, op cit., p.74.

<sup>6</sup>Ibid, p.69.



#### 2.1.4.3. Topography and Soil.

The topographic factors have perhaps the greatest influence on the selection of a method of applying irrigation water. Topography and soil influence the length of run, the length of time required for each irrigation. Erosion is also an important product of soil and topography.<sup>7</sup>

The degree of undulation that can be tolerated depends on the amount of leveling that is economically feasible, and whether gravity or sprinkler irrigation is contemplated.<sup>8</sup>

Lethbridge areas have a dark brown soil in the west which changes to brown in the east. These soils are generally of medium texture, non-saline and usually formed on, and of, riverine or aeolian deposits.

#### 2.1.4.4. Crops.

Certain crops such as corn, potatoes, onions, peas, sugar beets can be more readily cultivated and harvested when planted in rows. In this case furrow irrigation is a practical possibility and usually the least costly. But in Southern Alberta, most of these crops are irrigated by sprinklers.

Alfalfa is harvested several times each season and does not require cultivation to control weed growth while sprinklers are used. It is usually irrigated by corrugation, border or flooding from field ditches.

Alfalfa, corn, pasture, beans, sugar beets, flax, potatoes, wheat, were studied for this thesis.

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<sup>7</sup> Ibid, p.72.

<sup>8</sup> Handbook for the Classification of Irrigated Land in the Prairie Provinces, Committee of the Canada Department of Agriculture, Prairie Farm Rehabilitation Administration, Regina, Saskatchewan, 1964, p.29-30.



#### 2.1.4.5. Cost of Applying Water.

Where crops can be irrigated by one or more methods, the selected method is dependent upon both the initial cost and the annual operation cost. In many cases the first cost may be high but the annual cost, particularly the expenditure of labour, may be lower than any other method.

The cost of land development required to utilize some method of irrigation is derived from a computation of the amount of earth movement required to modify the topography, so that the particular method may be utilized.

The following table shows the influence of factors in selection of irrigation method.<sup>9</sup>

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<sup>9</sup>Paul H. Berg, op cit., p.80.



Table 1. Factors Influencing the Selection of a Method of Applying Irrigation Water.

Method of applying irrigation water (1)	Effective growing season rainfall (2)	Major Intake rate and capacity for available water in soil (3)	Influencing Factors Topographic relief and soils (4)	Crops to be irrigated (5)	Cost of applying water (6)
Furrow	Hazard of erosion down steep slope	Adaptable to most all soil textures	Uniform slopes of from 0.25% to 2.5%	Row crops (sugar beet) corn, cotton, vegetables (sugar cane, etc)	Most economical when uniform slopes are not over 2.5%
Corrugations	Can be used on comparatively steep slopes and heavy rainfall	Fine textured soils with low intake	Irregular fields, short run and slope up to 8.0%	Close growing crops (grains, hay, and some vegetables)	Most economical in first cost. Requires moderate labour
Borders	Can distribute water rapidly. Not damaged by heavy rain	Not desirable on fine textured soils with low intake rate	Smooth uniform slopes of not over 3.0%	Small grains, hay and pasture	Economical where heavy land grading not required. Moderate labour required.
Basins	Will accommodate heavy rainfall with required drainage	Adaptable to all soil textures	Level land	Most all crops. Only method for rice.	Where heavy land leveling not required costs are moderate. Labour costs are minimum
Flooding	Heavy rainfall permissible	Coarse to medium textured soils with high intake rate	Irregular field and topography with slopes up to 8.0%	Pasture or native hay	First cost very low. Annual labour high for 100% coverage
Sprinkler	Heavy rainfall permissible	All soils but particularly good on coarse textured soil	Undulating topography permissible with slope of no consequence	All crops except rice	First cost, annual O & M and labour costs are high
Sub Surface	Rainfall no item with controlled subsurface drainage	Loam or sandy loam soils with good lateral movement of water	Surface should be smooth and parallel to water table	Most all crops except orchards and rice	Minimum first cost and minimum labour cost



## 2.2. METHODS ENGINEERING

### 2.2.1. Introduction

Engineering is primarily concerned with the application of analytical methods, principles of physical and social sciences, and the creative process of the problem of converting raw materials and other resources to forms that satisfy the needs of mankind. The process involved in solving this conversion problem is ordinarily referred to as design.<sup>11</sup>

The problems dealt with by the various engineering specialties lend themselves very appropriately to the problem characterization and problem solving procedures introduced herein, for each concerns itself with a transformation from one state of affairs to another. For example, an engineer who is concerned with the energy transformation tries to transform the energy from its natural state to energy in a readily usable form. Broadly speaking, state A is energy in the form of coal, oil, the atom, the sun, or water at an elevation. State B is the useful energy, usually in mechanical form, such as the output of the steam or internal combustion engines, the turbine, and the jet engine.<sup>12</sup>

### 2.2.2. Methods Engineering

Methods engineering which is a phase of industrial engineering, involves:

1. method design (method study), and,

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<sup>11</sup> Edward V. Krick, Methods Engineering, John Wiley & Sons Inc., New York: 1962, p.82.

<sup>12</sup> Ibid, p.71.



2. work measurement (time study).

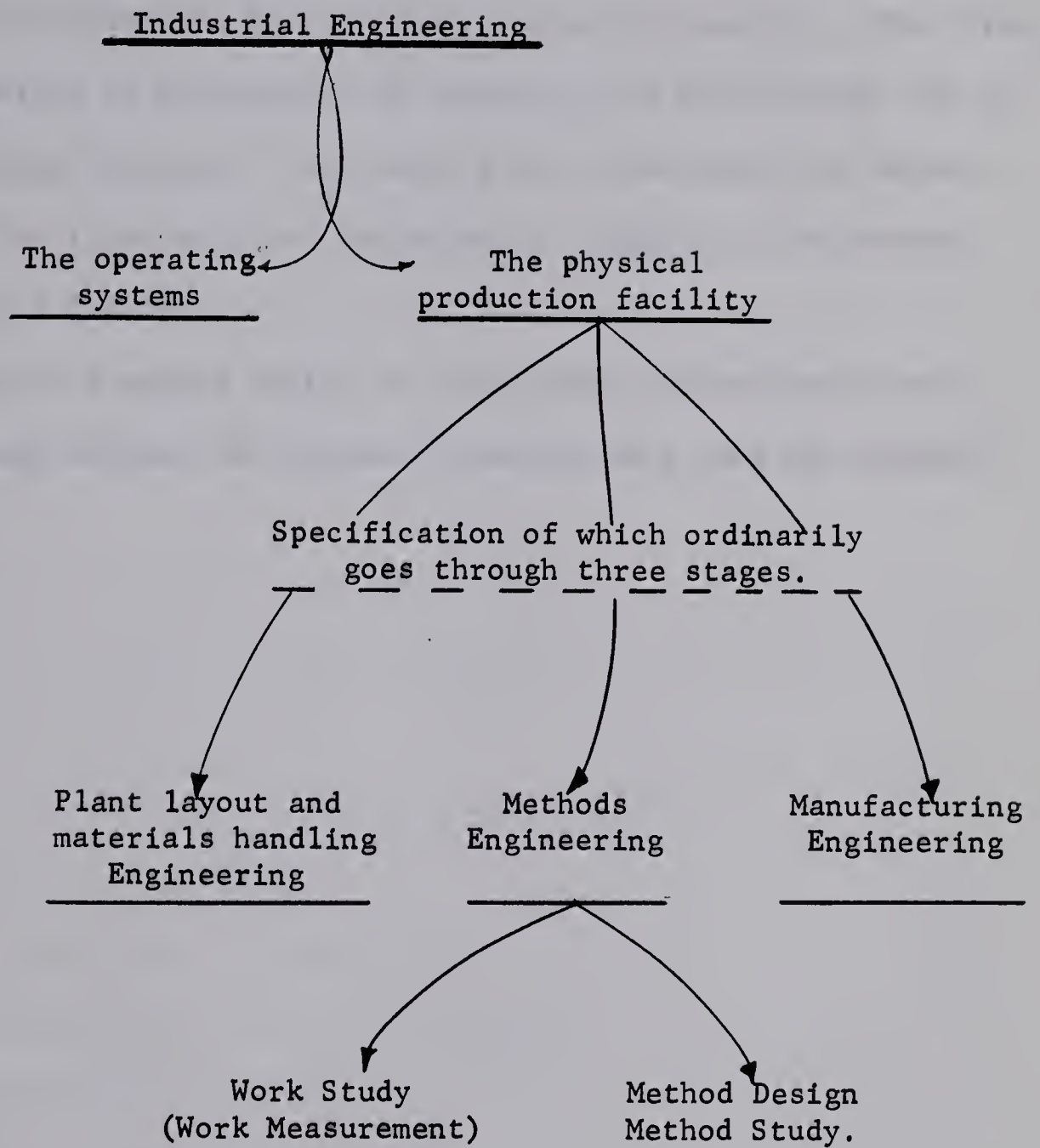


Figure 1. Relation of Methods engineering to Industrial Engineering.\*

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\*Note: Edward Krick, Methods Engineering, John Wiley & Sons Inc., New York: 1962, p.85.



Methods engineering is concerned with the human being in a productive process. The position and scope of methods engineering is indicated graphically in Figure 1.<sup>13</sup> As it will be noticed, there are two phases to the methods engineering function. The first, methods design, is the process of designing the work method. It is truly a design activity. The second phase, time study, is an outgrowth of the first as it is described in Part IV. The product of time are S.T.V.'s.

Examples of method design in this study, are automatic end-plug drainage valves, new methods of moving sets, and new methods of layout.

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<sup>13</sup>Ibid, p.85.



## 2.3. TIME STUDY

### 2.3.1. Definition of Time Study

Time study is a work measurement technique to determine the time required by a qualified and well-trained person working at a normal pace to do a specified task. Time study involves measurement. Time study is used to measure work.<sup>14</sup> The time in minutes that a person, suited to the job and fully trained in the specified method, will need to perform the job if he works at a normal or standard tempo, is called the STANDARD TIME for the operation, and is expressed as S.T.V. which means Standard Time Value, in this thesis.

It should be noticed that time study is only one of the work measurement techniques.\* Work measurement may be carried out by the following techniques:

1. time study (including production study);
2. ratio - delay study,
3. synthesis from standard data,
4. predetermined motion time standards,
5. analytical estimating,
6. chronocyclography.

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<sup>14</sup>International Labour Office, Introduction to Work Study, Geneva, 1962., p.191.

\*Note: Work measurement is defined by the British Standard 3138: Glossary of terms in Work Study, 1959, as "Work measurement is the application of techniques designed to establish the work content of a specified task by determining the time required for carrying it out at a defined standard of performance by a qualified worker." For more information refer to the list of references as in the Bibliography.



From the above techniques, time study has been used in irrigation, as it is the basic technique of work measurement.

Time study data may be used for the following purposes:

1. determining schedules and planning work,
2. determining standard costs and as an aid in preparing budgets,
3. estimating the cost of production,
4. determining machine effectiveness,
5. determining time standards to be used as a basis of a payment of a wage incentive to direct labour,
6. determining time standards to be used as a basis for labour cost control.

In irrigation it can, and has been, used for labour cost determination and comparison in different systems of irrigation, and it can, and has been, used to determine the basic time standards for recommended methods found by the application of methods engineering techniques.

### 2.3.2. Watch Reading

To record the time of elements, a recording device such as a stop watch, or others such as an electrical timing device is need. A stop watch was used for this study.

There are three alternative methods of timing by stop watch.<sup>15</sup>

1. Continuous reading.
2. Repetitive of fly-back timing.
3. Differential timing.

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<sup>15</sup> British Standard Institution, Glossary of Terms in Work Study, (UDC 001.4:65.015) London, 1959. p. 18-19.



#### 2.3.2.1. Continuous reading.

This is a method in which the hands of the stop watch are allowed to continue to move without returning them to zero at the end of each element, the time for each element being obtained subsequently by subtraction. Table 4 shows the description of elements.

#### 2.3.2.2. Fly-back timing.

Two watches are used: one is used for the cycle time, the other watch starts at the beginning of each element and snaps back to zero at the end of the element by pressure on the top of the winding knob. The validity of the study is improved by comparing the sum of the element times with the cycle time (total elapsed time).

#### 2.3.2.3. Differential timing.

This is a method for obtaining the time of one or more small elements. Elements are timed in groups, first including, and then excluding each small element, the time for each element being obtained subsequently by subtraction.

In irrigation, fly-back stop watch reading was chosen because:

1. the readings are immediately usable for calculations without subtractions or other arithmetic;
2. snap back is quicker and easier.

The recorded time for each element is recorded in hundredths of a minute, and this is called "Observed Time" for performing an element. (Abbreviated OT).



### 2.3.3. Rating

All observed times are not necessarily comparable, as the pace or tempo of performing an element may vary. One worker may finish the same job in a short time, while another may perform it in a longer time, although the quality and quantity remain the same. The observer has to have some means of assessing the rate of working of the operator under observation and relate this to a standard pace, by Performance Rating.

Rating is the mental comparison by the work-study man of the performance of an operation under observation with the agreed concept of standard performance for a given method.<sup>16</sup>

Since rating is a comparison between the level of performance, there should be a level to compare. This level is called NORMAL PERFORMANCE.

Normal performance (pace) is the working rate of the average worker working (under supervision) but without the stimulus of an incentive wage-payment plan. For example, for walking this is 3 mph compared with 4 mph at incentive pace.

### 2.3.4. Rating Scale

Figure 2. shows the four most common rating scales used in industrial engineering studies. It should be noticed that there are other systems of rating, such as Westinghouse, (USA Day Rate), BSI 0/100 Bedaux (UK Day Rate) and 75/100. F.J. Neole<sup>17</sup> believes that any data that has been levelled by the Westinghouse scale will be 11% (tight) for UK day work conditions.

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<sup>16</sup> International Labour Office, op cit., P - 235 - 238

<sup>17</sup> For more details refer to Work Study and management journal, Volume 10, No. 3, March 1966. p.121-124.



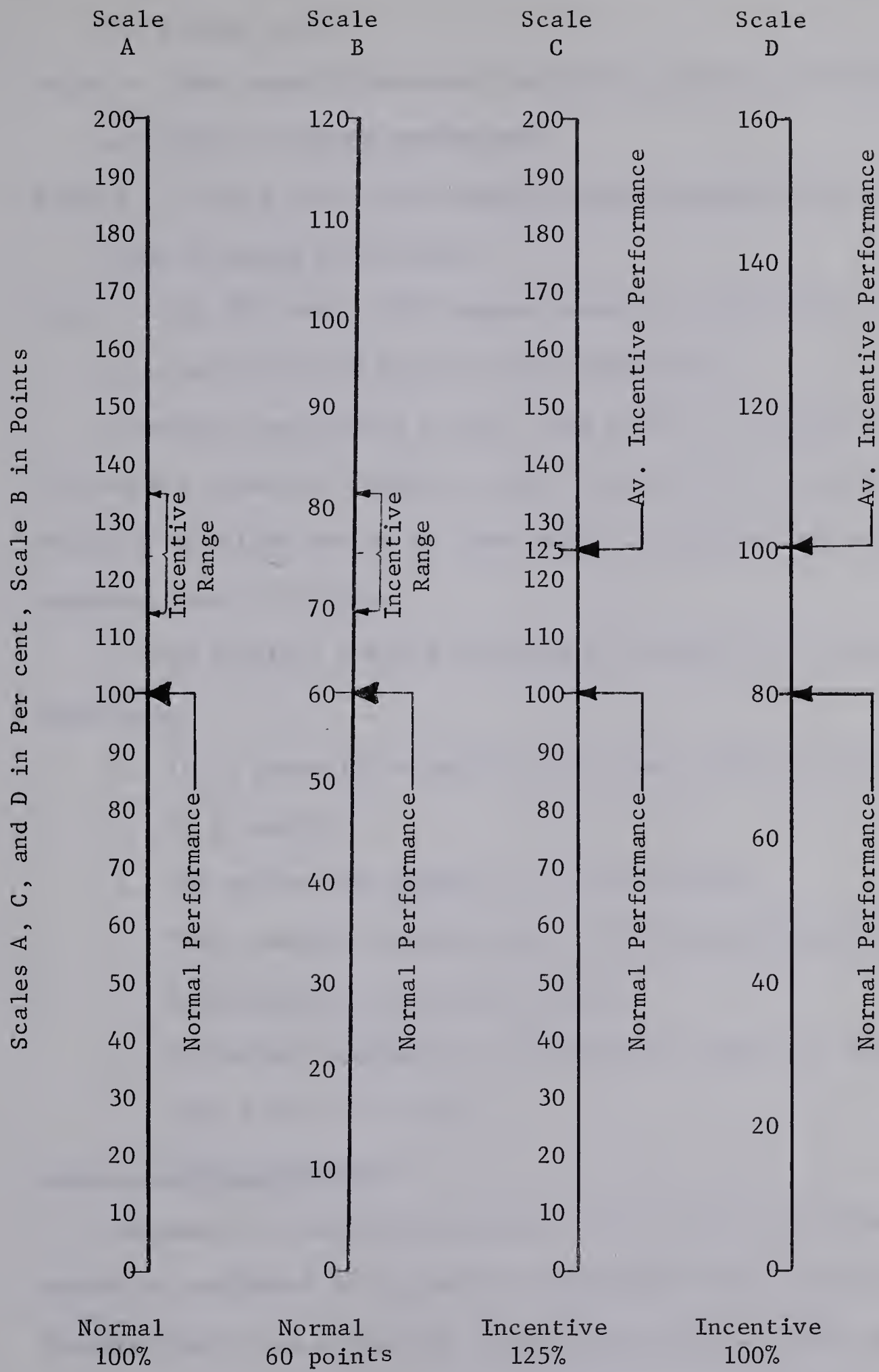


Figure 2. Rating Scale.\*

\*Note: Ralph M. Barnes, Motion and Time Study, John Wiley & Sons, New York, p. 398.



Scale A: In this scale the normal performance equals 100% on the rating scale.

Scale B: This scale illustrates the points system and 60 points are equal to normal performance.

Scale C: In this scale 125% equals incentive performance and 100% is normal performance.

Scale D: In this scale 100% equals incentive performance, or in other words 80% equals normal performance.

Incentive performance is that rate used by a qualified individual following a specified method in such a way that his average output during a specified period of time equals or exceeds the established standard level of output.

In the studies, Scale D was adopted because of the following advantages.

1. It is generally accepted as the most commonly used in Canada.
2. It is metric.
3. The writer was trained to use this method.

This, despite the above fact, is not the British Standard Specification recommended scale.

4. It is more convenient to normalize to 100 on a slide rule than a 60 or 80 scale.

#### 2.3.5. Rating Correction

Because the rating can be said to be a personal judgment, it should be subjected to correction (adjustment) from time to time. Because there is a scientific basis to the rating, there is a relation between observed time and given or observed rate.



(Observed time)(Observed rate) = Constant

or

$$T_1 \times R_1 = T_2 R_2 = T_n R_n = C \text{ for the same element} \quad (1)$$

T = observed time.

R = observed rate.

C = constant.

From this relation, the skill of rating could be corrected and improved. For example, at the beginning of this study the performance rating given by the writer was probably somewhat far from accurate. However, it was corrected to maintain a constant method of rating by the Rating Correction Methods as in Figure 3.

1. By recording a group of observations from the same element, and by giving an estimated rate, then finding out the average constant C, for the total number of observations in the group,

$$C = \frac{\sum T \times ER}{N} \quad (2)$$

There will be an adjusted rate for each observation if

$C_{\text{average}}$  is divided by observed times.

$$AR = \frac{C_{\text{average}}}{T} \quad (3)$$

In Tables 2 and 3, all AR's are calculated and then AR's have been plotted vs ER's. The dotted line in Figure 3 shows the estimated rates and the solid line shows the correct or adjusted rates.

Where:

T = observed time

ER = estimated rating

C = constant equal to  $T \times ER$  for each observation

$C_{\text{ave}}$  = average of all  $T \times ER$

N = number of observations in the group.



Table 2. Finding Average C.

Number	T In Minutes	ER Percentage	C C = ERxT
1	0.60	50	0.3000
2	0.40	80	0.3100
3	0.45	68	0.2970
4	0.40	73	0.2920
5	0.60	50	0.3000
6	0.30	110	0.3300
7	0.43	70	0.3010
8	0.40	75	0.3000
9	0.30	95	0.2850
10	0.20	120	<u>0.2400</u>
			<u>2.9550 = <math>\Sigma ER \times T</math></u>

$$C_{ave} = \frac{\Sigma ER \times T}{N} = \frac{2.9550}{10} = 0.2995$$

Using  $C_{ave}$  as a reference, then for each ER there will be a corresponding AR, as shown in the following table. Column (5) is the result of  $C_{ave}$  divided by Column (2) in table 3.



Table 3. Finding AR For Rating Correction.

<u>Number</u> <u>(1)</u>	<u>T</u> <u>In Minutes</u> <u>(2)</u>	<u>ER</u> <u>Percentage</u> <u>(3)</u>	<u>C</u> <u>(4)</u>	<u>AR</u> <u>Percentage</u> <u>(5)</u>
1	0.60	50	0.3000	49.25
2	0.40	80	0.3100	73.87
3	0.45	68	0.2970	65.67
4	0.45	73	0.2920	73.87
5	0.60	50	0.3000	49.25
6	0.30	110	0.3300	98.50
7	0.43	70	0.3010	68.72
8	0.40	75	0.3000	73.87
9	0.30	95	0.2850	28.50
10	0.20	120	0.2400	149.00

Note: (1) The size of the pipe is forty feet long by four inches in diameter (interior).

(2) The above figures have been taken from actual studies done by the author.



Now these ER and AR are plotted and the following curves will be produced, and the estimated rating will be adjusted.

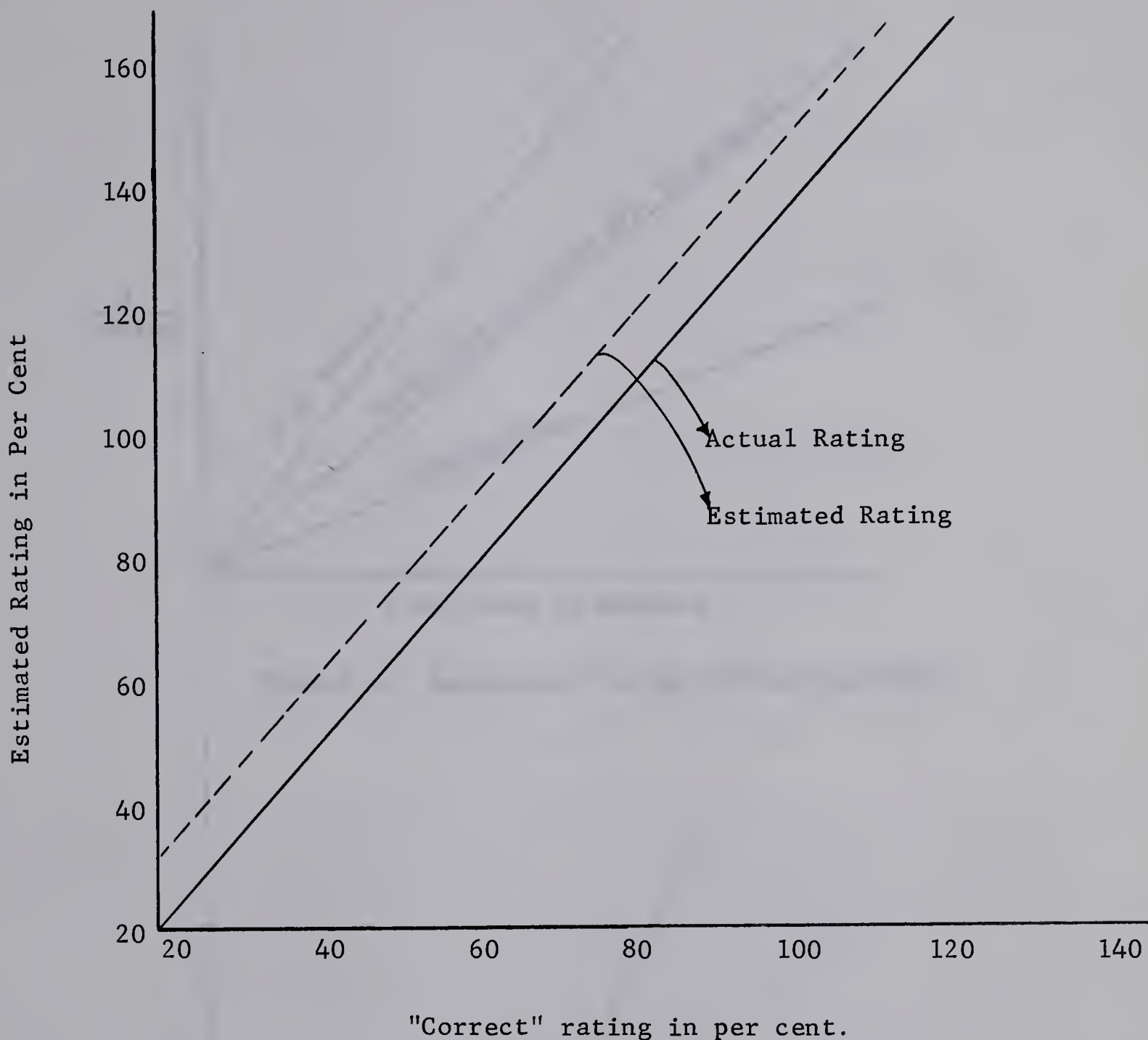


Figure 3. Rating Correction.

There are other methods of rating corrections. For example, the reciprocal method which can be seen in Figure 4. A tendency to over-rate is indicated in Figure 3. It was attempted to eliminate this over-rating in observations. Generally the observed times were not very far from actual time and most of them have been adjusted to actual rate.



Rating also could be corrected by comparison of the reciprocal-rate curve with the alternative curve as it is illustrated in Figures 4 and 5.

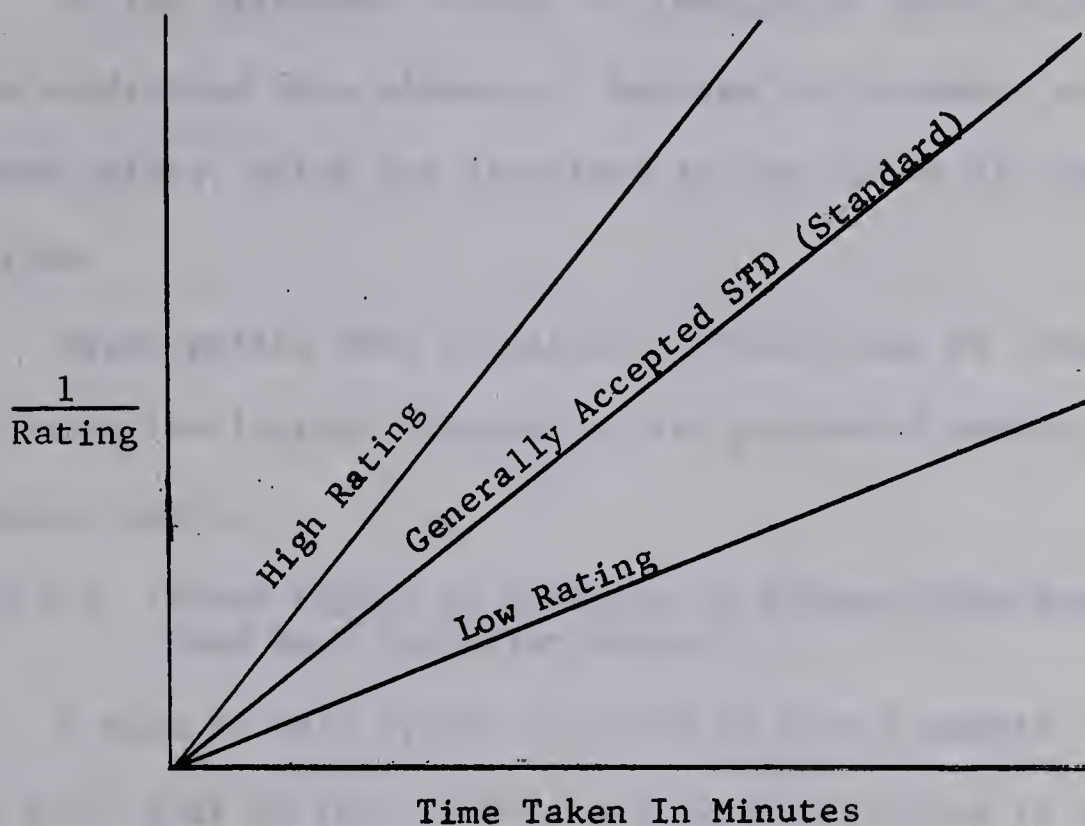


Figure 4. Reciprocal Rating Correction Curve.

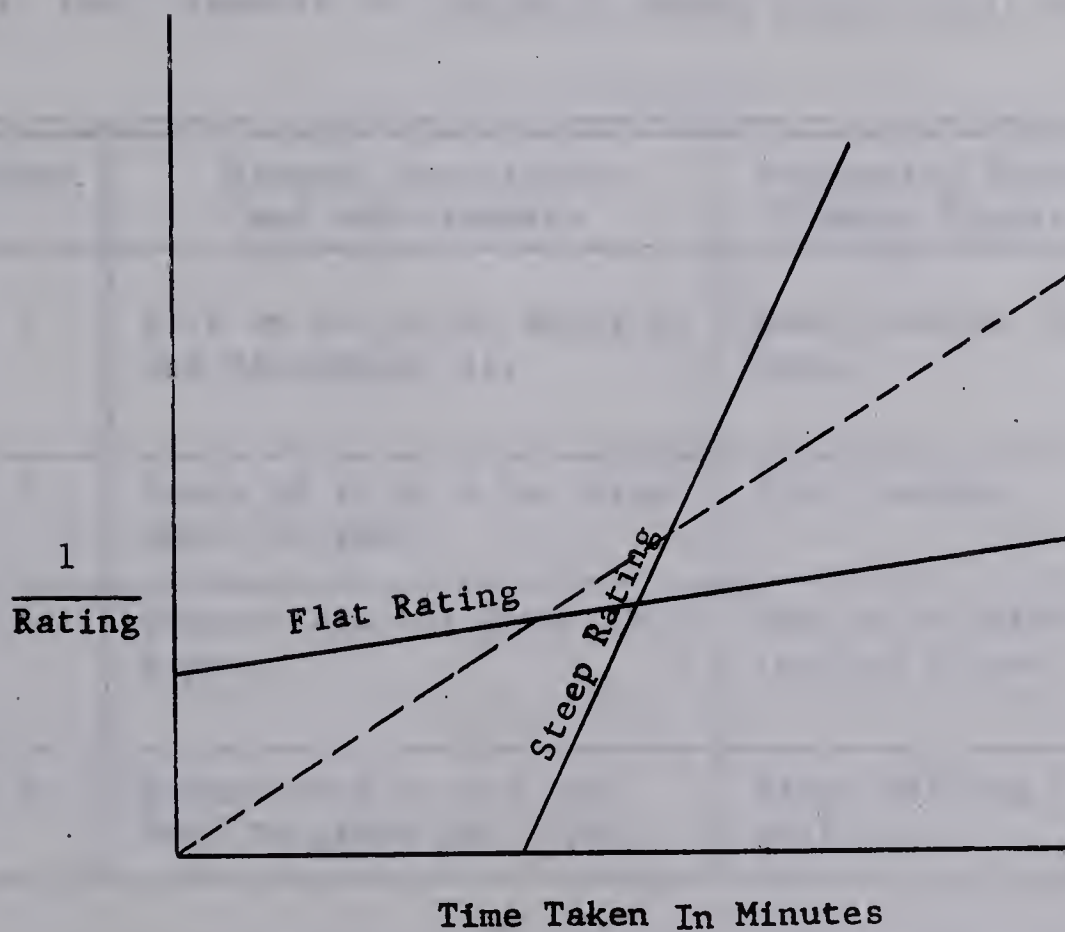


Figure 5. Reciprocal Rating Correction.



### 2.3.6. Elements

In the different systems of irrigation under study, each cycle was subdivided into elements. Between the elements are instantaneous break points, which are described in the tables of standard time values.

Break points were selected for their ease of observation and as being the logical division of the pattern of working into homogeneous parts.

#### 2.3.6.1. Break Points of Elements in Lateral Pipe Movement in Hand Move Sprinkler System

A pipe in this system is moved by four elements. Each pipe is forty feet by four inches, and lateral spacing is sixty feet between sets. Each element could be broken to smaller elements if desired. The main four elements are shown in table 4 with their break points.

Number	Element Description and Sub-elements	Breakpoint Starts Element Starts	Breakpoint Finished
1	Pick up the pipe, empty it and disconnect it.	Hand touches the pipe.	Pipe completely in hand and is emptied
2	Carry 40 ft by 4 in. pipe about 60 feet.	Start moving.	Stop moving at new position.
3	Connect and lay down the pipe.	One end of pipe touches ground.	Fully released after connections.
4	Return back to old set, bend to grasp new pipe.	Start walking back.	Touch the pipe.

Table 4. Breakpoints for lateral pipe moving.



Each cycle consists of moving a 40 foot length of aluminum pipe with a 4 inch diameter, from one position to another. The cycle includes four elements mentioned on page 29.

#### 2.3.7. Normal Time

Normal times are the product of the observed (average observed time), multiplied by the observed rating, divided by normal rating, where

$$NT = \frac{OT \times R}{NR} \quad (4)$$

NT = normal time.

OT = observed (average of observations time).

R = rating in percent.

NR = normal rating.

This normal time represents the time that the element would take to be performed by an operator working at a normal rate of performance.

If performance were above normal, then normal time is

$$NT = OT + \frac{OT(R-100)}{100} \quad (5)$$

If performance were below normal, then

$$NT = OT - \frac{OT(R-100)}{100} \quad (6)$$

Since these formulae all depend on acceptance of the concept of rating being accurate, a means of proving this accuracy is needed. Thus, validation of rating is of particular importance if S.T.V. are to be accepted as accurate, and as mentioned, this is done by rating correction.



### 2.3.8. Allowances

Before a time standard for an operation is completed, it is necessary to add to the normal time certain allowances. According to the International Labour Office publication, a classification of these allowances is:

1. process allowances,
2. rest and personal allowances,
3. special allowances,
4. policy allowances.

The rest and personal allowances are included in the term of "relaxation allowances," in these studies:

The normal time is the basis of all allowances. The normal time is thus applicable to those periods in which the operator is able to work. There are many small periods in which the operator is prevented from working; by such things as equipment unsuitability, failures, (as was observed in starting the mover engine in wheel-move systems), stoppage of material flow. During these, rest to overcome fatigue maybe taken, but they will not occur so that the time may be taken for personal needs, defective parts, unfavorable conditions as wind, cohesion or moistured soil, and other factors causing delay and fatigue. Since these are ordinarily beyond the operator's (irrigator) control, it is necessary to make some provision for such delaying and retarding factors in the time standards. The actual observed times in fields are a relatively short span of time such that the sample includes few or none of the numerous delays. The period of observation that is adequate for ordinary cycles does not suffice as a sample period for delays.



To be able to use the standard time values universally, the normal time for similar conditions can be taken and by adding condition allowances, these could be used in any irrigation area. Allowances are the amount of time added to normal time to provide for unavailable production delays, personal delays, the effects of other factors such as wind, crop height, and so forth. This is an adjustment that depends on many factors in different conditions and operations.

In these studies, personal and basic fatigue allowances have been calculated and are taken to be 9% of the normal time. As most of the jobs have been performed standing, then 2% for standing allowances, and also in many tasks, some allowances for abnormal positions such as bending or other awkward positions have been added.

Some allowances for weight or pushing and use of muscular energy and tediousness from duties, and crops, have been added.

Wind velocity has two effects; one as a fluid exerting pressure on the surface of equipment, such as pipes, during most operations and causing delay that could be noticed in standard time value tables. The second effect is that of wind on body cooling. As the tables used by the International Labour Office of United Nations and others appeared to be incomplete for Alberta conditions, a new table was calculated and is given as table 5.

The following wind chill chart has been used for a practical guide for atmospheric conditions. A temperature-wind combination and allowances for different wind and temperatures have been added by using this chart as an Index.

#### 2.3.8.1. Summary.

Personal	9%
Standing	2%
Weight of Pipe	4% (per 10' of length for aluminum pipe 4 inches in diameter weighing 0.74 lb per foot.)



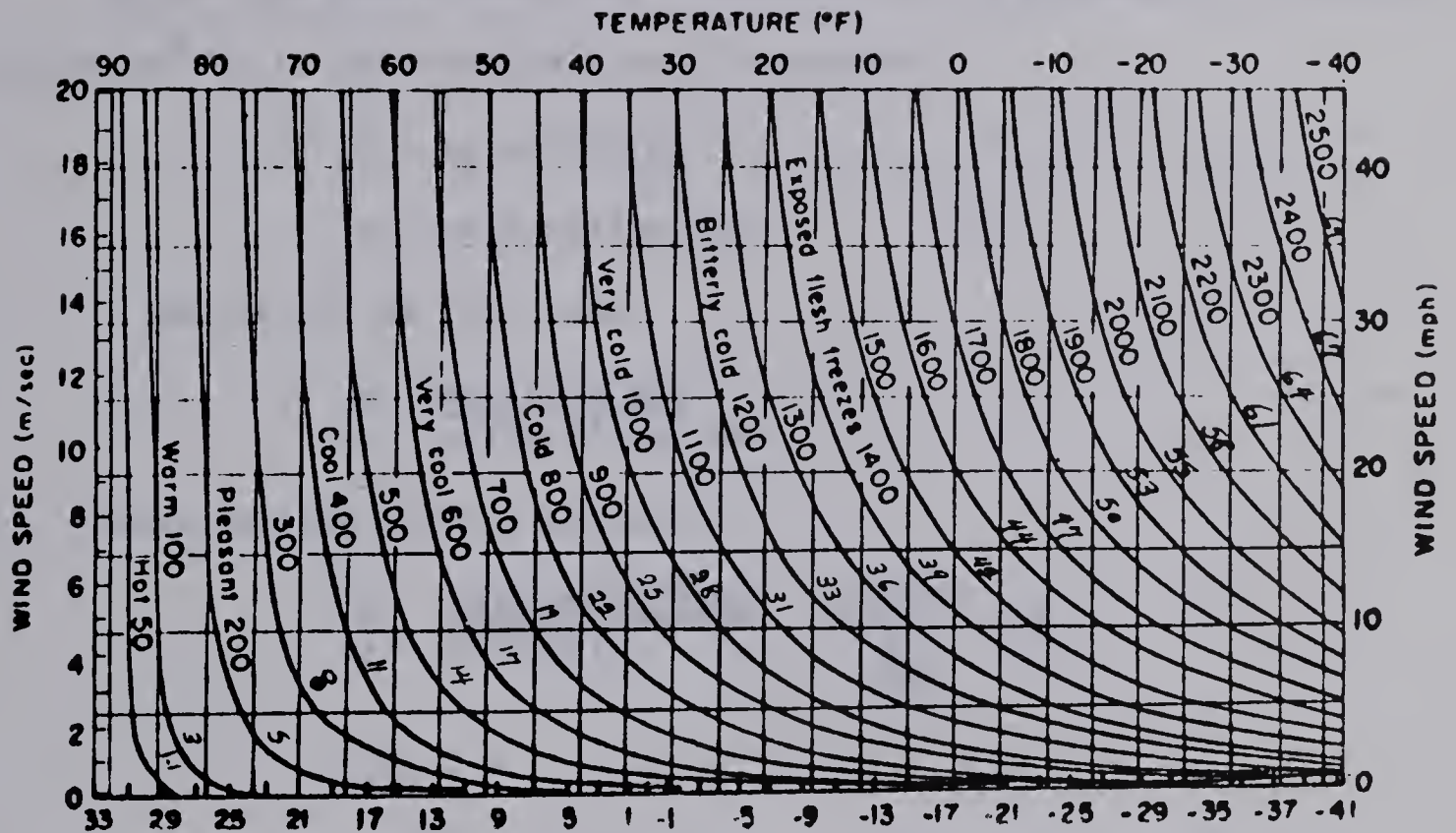


Figure 6. Windchill chart.

Numbers on curves on the top represent wind-chill in  $\text{kg-cal/m}^2/\text{hr}$  (Falkowski and Hastings, 1958)\*

The lower figures are their equivalent in  $\text{mill-cal/cm}^2/\text{second}$  (by writer 1966) in manuscript.

\*Note: C.T. Morgan, et al, Human Engineering Guide to Equipment Design, McGraw-Hill, New York, 1963.



Atmospheric Conditions (wind, temperature) can be seen in Table 5.

Here rest allowances include constant allowances, variable allowances, muscular energy allowances, and atmospheric allowances. The atmospheric allowances have been calculated from windchill chart.<sup>18</sup>

To use the above chart for allowances it is necessary to convert  $\text{kg-cal/m}^2/\text{hr}$  to  $\text{mill-cal/cm}^2/\text{sec}$ ., therefore:--

$$x = \text{kg-cal/m}^2/\text{hr} \quad (7)$$

$$y = \text{mill-cal/cm}^2/\text{sec} \quad (8)$$

Divide (7) by (8), then:

$$\frac{x}{y} = \frac{\text{kg-cal/m}^2/\text{hr}}{\text{mill-cal/cm}^2/\text{sec}}$$

Substituting uniform units:

$$\frac{x}{y} = \frac{1000/10000/3600}{1/1000/1/1} = \frac{1/36000}{\frac{1}{1000}} = \frac{1}{36}$$

$$36x = y \quad (9)$$

or

$$36(\text{kg-cal/m}^2/\text{hr}) = 1(\text{mill-cal/m}^2/\text{sec})$$

Table 5 shows the allowances calculated for Alberta atmospheric conditions.

Table 5. Allowances for Atmospheric Conditions

Cooling power in $\text{mill-cal/cm}^2/\text{sec}$	Cooling power in $\text{kg-cal/m}^2/\text{hr}$	Allowance %
16	576	-
14	504	-
12	432	-
10	360	3
8	288	10
6	216	21
5	180	31
4	144	45
3	108	64
2	72	100

<sup>18</sup>C.T. Morgan, et al, Human Engineering Guide to Equipment Design, McGraw-Hill, New York, 1963. p.433.



### 2.3.9. Standard Time.

Standard time is defined as the total time in which a job should be completed at standard performance, i.e. work content, contingency allowance for delay, unoccupied time and interference allowance, where applicable.<sup>19</sup> These are called in some books, "time standards." In this thesis they will be called STANDARD TIME VALUES, which are abbreviated and referred to as S.T.V.

S.T.V. is calculated from the following formula:

$$S.T.V. = NT + (NT \times \%A11) \quad (10)$$

where: S.T.V. = standard time value  
NT = normal time  
A11 = allowances.

S.T.V. could be also calculated from the following formula:

$$S.T.V. = \frac{OT \times R}{100} + (\%A11 \times \frac{OT \times R}{100}) \quad (11)$$

where: S.T.V. = standard time value in minutes  
OT = observed time in minutes  
R = observed rate  
A11 = allowances in percentage of normal time.

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<sup>19</sup> British Standards Institution, Glossary of Terms in Work Study, B.S. 3138:1539, London, 1959. p.23.



## PART III

### INVESTIGATIONAL PROCEDURE

#### 3.1. Introduction

There has been much work done with respect to identifying the degree of the effects of various factors governing the selection of irrigation methods. Labour consumption and related cost is one of the major costs of irrigation and yet no accurate data is available.

On the other hand, the various techniques of methods engineering and industrial engineering have been applied to many industrial and agricultural enterprises, and as professor C.de Lauwe (France), professor A. Moens (Netherland), professor G. Preuschen (Germany), the members of O.E.C.D. Committee stated there is no reference or source to show the application of methods engineering to irrigation. Therefore, because of the combination of the past experience of the writer and his interest in irrigation and the guidance of interested professors at the University of Alberta, the subject of this thesis was selected for investigation. The first step was to make contact with farmers and then to make a pilot study.

#### 3.2. Area of Research and Number of Systems

After selection of the topic, the University contacted engineers and research officers in the Lethbridge area. The Southern part of Alberta was chosen as the location for data collection. The irrigation systems in which this study was done may be found on the map given at Appendix G: They were located as shown in Table 6.



Table 6. Location and Number of Systems Studied.

District	Methods					TOTAL
	Gravity		Sprinkler			
	Flooding Number	Gated Pipe Number	Hand-move Number	Valley System Number	Wheel-Move Number	
Bow Island	2	-	4	2	3	11
Coldale	3	-	6	-	-	9
Lethbridge	2	2	2	-	-	6
Taber	1	-	4	-	-	5
Vauxhall*	-	-	4	-	1	5
Total of Each System	8	2	20	2	4	36

\*Note: One Tri-matic system which is a new mechanical move sprinkler system, was demonstrated only for a few days at the Vauxhall area.

To visit these systems, 9000 miles were driven from mid-May to mid-September; the data were collected between 4:30 A.M. and 8:30 P.M. This major work of recording did not leave time for the analysis of data until the academic year began. Analysis of data continued until January, 1966, and results were produced.

### 3.3. Elements.

For a Pilot Study the main irrigation tasks were subdivided into elements for ease during a Pilot Study of timing. These elements were described under Part II and Appendix "A", Table 4 p. 29.



Because of the effects of various factors described in Part IV, the recorded times in the Pilot Study were not particularly constant. As a result, of one hundred and nineteen samples were taken, and from these the number of observations for an accurate study was determined.

#### 3.4. Determination of Number of Observations required for 95 per cent confidence in S.T.V.

Generally it is found that the greater the number of elements timed, the more accurate the results will be, and thus be representative of the activity being timed. For the desired accuracy of the results obtained here, one of the several statistical theorems have been used to determine the number of elements or cycles to be timed. With a 95 percent confidence level and  $\pm 5$  percent precision which is normally acceptable in work study, the necessary number of observations can be found. This means that the chances are that at least ninety-five out of one hundred of the results of the average of elements will not be in error more than  $\pm 5$  per cent of the true element time.

A total of 119 observations were taken and the following formula used to determine the size of the whole.

$$N' = \left( \frac{40y \sqrt{N \times \sum y^2 - (\sum y)^2}}{\sum y} \right)^2 \quad (12)$$

Where:

- $N'$  = required number of observations to predict the true time within  $\pm 5$  per cent precision and 95 per cent confidence level.
- $N$  = observed elements number that here is 119.
- $y$  = individual watch readings in minutes.
- $y^2$  = square of individual watch readings after normalization.



Table 7. Calculation of  $y$  and  $y^2$  From Observed Time.

$y$	$y^2$	$y$	$y^2$	$y$	$y^2$	$y$	$y^2$
0.1800	0.032400	0.0720	0.005184	0.1650	0.029225	0.0600	0.003600
0.1920	0.036864	0.0720	0.005184	0.3000	0.090000	0.0960	0.009216
0.3600	0.129600	0.0720	0.005184	0.1200	0.014400	0.0960	0.009216
0.8800	0.774400	0.0720	0.005184	0.1800	0.032400	0.0600	0.003600
0.8800	0.774400	0.0720	0.005184	0.3000	0.090000	0.0720	0.005184
0.7200	0.518400	0.0750	0.005625	0.1800	0.032400	0.0600	0.003600
0.2200	0.048400	0.0960	0.009216	0.1800	0.032400	0.0760	0.005886
0.4920	0.242064	0.0720	0.005184	0.1800	0.032400	0.2200	0.048400
0.3600	0.129600	0.0600	0.003600	0.1800	0.032400	0.3000	0.090000
0.2520	0.063504	0.0720	0.005184	0.1800	0.032400	0.4200	0.176400
0.2160	0.046656	0.0960	0.009216	0.1800	0.032400	0.4200	0.176400
0.1200	0.014400	0.1080	0.011664	0.1200	0.014400	0.3200	0.102400
0.0960	0.009216	0.1080	0.011664	0.3600	0.129600	0.4200	0.176400
0.0960	0.009216	0.0960	0.009216	0.3000	0.090000	0.4200	0.176400
0.2880	0.082744	0.1080	0.011664	0.4200	0.176400		
0.4200	0.176400	0.2880	0.082944	0.3000	0.090000		
0.3000	0.090000	0.0750	0.005625	0.3000	0.090000		
0.0960	0.009216	0.9600	0.921600	0.4300	0.184900		
0.0960	0.009216	0.1320	0.019424	0.4500	0.202500		
0.1260	0.015876	0.0720	0.005184	0.3450	0.122500		
0.0840	0.009056	0.0720	0.005184	0.2500	0.062500		
0.1950	0.038025	0.1080	0.011665	0.3000	0.090000		
0.0780	0.006084	0.1200	0.014400	0.3450	0.122500		
0.0875	0.007656	0.4500	0.202500	0.1200	0.014400		
0.7200	0.518400	0.1200	0.014400	0.9600	0.921600		
0.1200	0.014400	0.1100	0.012100	0.3000	0.090000		
0.7200	0.518400	0.1200	0.014400	0.8800	0.774400		
0.0750	0.005625	0.1200	0.014400	0.1200	0.014400		
0.0960	0.009216	0.1300	0.016900	0.1080	0.011664		
0.0720	0.005184	0.2280	0.051984	0.0960	0.009216		
0.0520	0.002704	0.1200	0.014400	0.1080	0.011664		
0.2100	0.044100	0.1200	0.014400	0.0840	0.007056		
0.0840	0.007056	0.1200	0.014400	0.0960	0.009216		



Table 7. Calculation of  $y$  and  $y^2$  From Observed Time. (Cont'd)

$y$	$y^2$	$y$	$y^2$	$y$	$y^2$	$y$	$y^2$
0.1100	0.012100	0.1200	0.014400	0.0720	0.005184		
0.0960	0.009216	0.1200	0.014400	0.0720	0.005184		
$\Sigma y =$	$\Sigma y^2 =$	$\Sigma y =$	$\Sigma y^2 =$	$\Sigma y =$	$\Sigma y^2 =$	$\Sigma y =$	$\Sigma y^2 =$
9.1895	4.417994	4.9560	1.570862	9.0810	3.697798	3.0400	0.987592

$y$  = individual watch readings in minutes

Operation: Lateral pipe change in sprinkler hand move

Element: Emptying and pick up of pipes.

The totals are:

$$\Sigma y = 26.2665$$

$$\Sigma y^2 = 10.673157$$

$$N' = \left( \frac{40 \sqrt{N y^2 - (\Sigma y)^2}}{\Sigma y} \right)^2$$

$$\therefore = \left( \frac{40 \sqrt{(119 \times 10.673157) - (26.2665)^2}}{26.2665} \right)^2$$

$$\therefore = \left( \frac{40 \sqrt{1270.105683 - 689.92902225}}{26.2665} \right)^2$$

$$\therefore = \left( \frac{40 \sqrt{580.17466075}}{26.2665} \right)^2$$

$$\therefore = \left( \frac{40 \times 24.08}{26.2665} \right)^2$$

$$\therefore = \left( \frac{963.20}{26.2665} \right)^2$$

$$\therefore = (36.67)^2 \approx (37)^2 \quad (13)$$

$$N' = 1369 \approx 1370 \text{ observations.}$$



For a confidence level of 95 percent and a precision of  $\pm 5$ , about 1370 observations were needed. Over 1500 observations were recorded for this research project.

It should be noticed that there are other methods of finding the number of observations, but here this method has been used and tested.

Many writers in work sampling have presented monograms for determining sample size since the speed of calculation is greatly increased over use of formulae and the possibility of gross error is reduced. A.D. Maskowitz presented a nomogram in August 1965.

This differs from the previously used nomogram in that both the confidence limits and range of probability can be assessed simultaneously.

The number of observations needed in this study were tested by this nomogram and it was found that for a precision of  $\pm 5$  percent and confidence level of 95 percent, 1400 samples are needed.<sup>21</sup>

### 3.5. Rating Correction

After the total number of required observations was determined, it was noted that the rating given by writer was high. This was corrected and adjusted by two methods. During the study, a new way of Rating Correction was developed. This method is under "Time Study" in Part II. 23.5. p.23.

### 3.6. Normalization of Times.

The observed time and given records were collected from various parts, and then they were normalized and tabulated as in Appendix H. For formulae of 4,5,6 normalization refer 2.3.7. p.30.

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<sup>21</sup> Institute of Work Study Practitioners  
Work Study and Management, Vol. 9, No. 8, August, 1965. p. 350.



### 3.7. Allowances

For conditions under which irrigation jobs are done in Alberta, certain extra allowances are required: the guidance of related books and charts was used to add these allowances to the normalized times to calculate standard time values (S.T.V.) The table and chart of allowances can be seen in Part II under Allowances, 2.3.8 p. 31, 23.8.1, p. 32.



## PART IV

### RESULTS

The following results were obtained after analyzing the collected data:

- 4.1. S.T.V. Tables, compiled by December 1965 and January 1966.
- 4.2. Relation of Factors, developed in February and March 1966.
- 4.3. Identification of formulae governing relations also found in February, 1966.
- 4.4. Labour Requirements, partly completed in mid-September 1965, completed mid-March 1966.

#### 4.1. Standard Time Values

Standard Time Values are tabulated and are in Appendix "A", where they are referred to occasionally as S.T.M.

#### 4.2. Relationships of Factors Affecting Labour Requirement

##### 4.2.1. Factors affecting time requirement of elements.

There are many factors that have been shown to affect the required S.T.V. for operations in irrigation methods. Results showing the effects of various main factors are shown in following tables. These results are discussed in the following.

##### 4.2.1.1. Wind.

One of the factors that delay lateral pipe movement in the hand move systems is wind, especially in Alberta. This factor not only affects the distribution and uniformity coefficient, but it also affects the time for carrying pipes, and the time for connection. This is due to the forces that the wind exerts on the pipe causing it to swing.



Tables 8 - 16 in this section show these effects.

#### 4.2.1.2. Soil Moisture.

As the percentage of soil moisture due to irrigation or rain increases, the walking times also increases. In dry soil it is easier and faster than in wet soil, to walk while carrying objects. It should be mentioned here that as the depth of saturated or wet soil increases the S.T.V. will also increase directly.

#### 4.2.1.3. Crops.

Carrying, connecting and picking up the pipes are all easier in some crops and harder and longer in other crops. It is easier to move pipes in alfalfa than in flax.

#### 4.2.1.4. Height of Crops.

As the height of crops increases, the time needed for moving pipes increases also. This is because there will be more friction between plants and the worker. This causes delay.

This delay is due to:

- I. obstructions to movement,
- II. connection is more difficult by obscured vision,
- III. pipes are difficult to lay and they must be checked after water flows in them,

#### 4.2.1.5. Topography (Drainage).

This factor is one of the most important ones because the roughness of the land causes a delay in pipe drainage if the pipes are not equipped with a drainage valve.



#### 4.2.1.6. Muddiness.

When the land has been irrigated and the equipment has to be moved to a dry area, fifty per cent of walking distances (30 feet) are very muddy. The normal time for walking in irrigated land is also affected by the type of crop, height of crop, wind velocity, condition of soil surface due to the cohesion force, irregularities causing small ponds, streams and other water-logged conditions.

Within the range of the experiment it was found that there was no significant influence of temperature or humidity. This result may not be correct for temperatures and humidity beyond the range of  $40^{\circ}$  -  $92^{\circ}$  and 8% - 90% Relative Humidity. The effects of perspiration would increase the normalized time, and definitely would influence the rest allowance included in the standardized time.

The following symbols represent the effect of the various factors influencing normal time for walking in irrigated lands.

$$NT = f(C.H.WV.SC.M.L.T) \quad (13)$$

#### 4.2.1.7. Others.

It is explained that the concept of rating implies an average worker. The times are only valid if allowances are made for:

1. age - older men need more rest than youths,
2. lack of skill, a training allowance should be considered,
3. the need for protective clothing.



Where: NT = Normal time for walking a unit of length in  
minutes,  
C = crop  
H = height of crop in inches  
WV = wind velocity in mph.  
SC = soil cohesion force in psi.  
M = muddiness

The exact relationships are not clear and could be either linear or non-linear, both or neither. The tables in this section and the following graphs, will show some of the relationships in greater detail.



Table 8. Effect of Crops! Height on walking unloaded for 60 feet.

Crop	Average Height in in.	Wind Speed mph	Temperature F°	Number of observations	Condition of Soil	Normal Time (min)	Remarks
Flax	18	6	80	72	Muddy	.4574	Insufficient points to plot any curve
Flax	21	6	76	64	Muddy	.4648	
Potato	7	6	58	56	Muddy	.4687	
Potato	13	6	48	72	Muddy	.5971	
Potato	7	4	60	80	Muddy	.4632	
Potato	9	4	68	56	Muddy	.5321	
Sugar beet	19	11	68	72	Muddy	.4872	
Sugar beet	21	11	73	48	Muddy	.5321	
Sugar beet	11	16	59	32	Muddy	.4791	
Sugar beet	19	16	76	64	Muddy	.5208	
Sugar beet	12	17	60	24	Muddy	.5094	
Sugar beet	20	17	62	88	Muddy	.5105	



Table 9. Factors affecting Standard Time Values for carrying a pipe 40 ft in length by 4 in. in diameter, for 60 feet.

Crops	Wind Speed in mph	Soil Moisture	Normal-ized time in (min)	No. of observ-ations	Crop's Height in (in.)	Notes
Sugar beets	17	Saturated	0.3758	176	18	With water ponds on surface
Sugar beets	19	Saturated	0.4145	56	18	
Sugar beets	17	Wet	0.3588	32	16	
Sugar beets	3	Wet	0.3879	48	20	
Sugar beets	15	Wet	0.4711	40	20	
Sugar beets	18	Wet	0.4821	32	22	
Sugar beets	11	Wet	0.3811	176	19	
Sugar beets	19	Saturated	0.4836	48	12	
Sugar beets	15	Saturated	0.4674	40	12	A large portion of soil surface was covered by ponds.
Sugar beets	6	Saturated	0.4469	56	19	
Sugar beets	6	Saturated	0.4606	32	20	
Flax	3	Saturated	0.3999	144	18	
Flax	5	Saturated	0.3749	48	15	
Beans	3	Too wet	0.5294	88	5	Ponds
Potatoes	5	Too wet	0.3989	88	6	Ponds
Potatoes	10	Too wet	0.4083	176	7	
Potatoes	12	Too wet	0.4149	128	8	



Table 10. Factors affecting the connection of lateral pipes in hand move Sprinkler Systems.

No.	Crops	Average Height of Crop (in)	Speed Of Wind (mph)	Average Normalized time (min)	Number of observations.	Note	Remarks
1	Beans	7.50	6.00	.1386	56		
2	Flax	16.00	6.00	.1462	72	(2)	
3	Flax	16.00	10.00	.1539	64	(1)	
4	Flax	22.00	6.00	.1610	56	(2)	
5	Flax	16.00	10.00	.1652	64	(1)	
6	Flax	16.00	10.00	.1673	52	(1)	Effect of land unevenness and roughness--soil characteristics.
7	Potatoes	6.50	2.00	.1459	80		
8	Potatoes	6.50	3.00	.1537	56		
9	Potatoes	6.50	5.00	.1668	48		
10	Potatoes	12.50	10.00	.1766	64		
11	Potatoes	6.50	7.00	.1790	48		
12	Potatoes	6.50	20.00	.1915	88		
13	Sugar beets	16.00	6.00	.1390	104	(3)	
14	Sugar beets	19.00	11.00	.1453	72		
15	Sugar beets	20.00	5.00	.1471	48		
16	Sugar beets	20.00	5.00	.1494	88		
17	Sugar beets	12.00	15.50	.1513	40		
18	Sugar beets	20.00	8.00	.1514	72		
19	Sugar beets	20.00	13.00	.1589	48		
20	Sugar beets	16.00	6.00	.1594	88	(3)	Effect of land unevenness and soil characteristics.
21	Sugar beets	20.00	15.00	.1596	56		
21	Sugar beets	12.00	16.50	.1613	32		
21	Sugar beets	18.00	17.00	.1618	88		

- Note: (1) In Flax there are three different normal times for each crop effect with the same crop height and wind velocity. These show the effect of topography and soil characteristics.
- (2) The effects of height could be seen in flax in line 2, 4.
- (3) The effect of roughness and unevenness of earth in sugar beets.
- (4) Size of pipe 40 ft by 4 in. in diameter, aluminum weighs 29.7 lbs.
- (5) Humidity and temperature measurements were not found to have significant effect on Normalized times.



Table 11. Effect of factors on standard time value for picking up the pipe.

Crop	Wind Speed (mph)	Average Normal Time (min)	Average Crop Height (in.)	Surface roughness, Slope of land.
Flax	15	.6402	15	Very rough
Flax	20	.2000	17	Not good
Flax	10	.6500	15	Very rough
Sugar beet	10	.1650	14	Good
Sugar beet	16	.0690	10	Steep slope one direction
Sugar beet	17	.5900	20	Very rough
Sugar beet	21	.2101	20	Slightly rough
Sugar beet	22	.6100	20	Very rough
Sugar beet	20	.4300	20	Rough
Sugar beet	3	.4800	17	Rough
Sugar beet	3	.4100	14	Rough
Potato	16	.2200	10	Good
Potato	10	.1900	10	Good
Potato	7	.6600	8	Very rough
Potato	3	.6100	6	Very rough
Potato	18	.0710	8	Steep, one direction
Beans	10	.4300	6	Rough
Beans	7	.5800	6	Very rough
Beans	10	.3100	6	Slightly rough
Beans	11	.3000	8	Slightly rough
Beans	10	.4900	8	Rough



Table 12. Factors affecting walking 60 feet unloaded in irrigation farms.

No.	Crops	Average Height of crop (in.)	Wind Speed (mph)	Average Normal Time (min)	Temperature F°	Number of observations
1	Beans	8	2	.5547	80	88
2	Flax	15	8	.4209	86	40
3	Flax	18	6	.4574	80	72
4	Flax	16	10	.4605	72	64
5	Flax	21	6	.4648	76	64
6	Potato	7	4	.4632	60	80
7	Potato	7	6	.4687	58	56
8	Potato	9	4	.5321	68	56
9	Potato	13	6	.5971	48	72
10	Potato	15	10	.6230	51	32
11	Potato	7	10	.6318	60	72
12	Sugar Beets	20	5	.4512	55	32
13	Sugar Beets	11	16	.4791	59	32
14	Sugar Beets	19	11	.4872	68	72
15	Sugar Beets	20	8	.4872	58	48
16	Sugar Beets	17	6	.5078	59	56
17	Sugar Beets	20	15	.5081	56	96
18	Sugar Beets	12	17	.5094	60	24
19	Sugar Beets	20	17	.5105	62	88
20	Sugar Beets	20	10	.5135	70	48
21	Sugar Beets	19	16	.5208	72	64
22	Sugar Beets	21	11	.5321	73	48
23	Sugar Beets	20	3	.5453	51	56

Fifty per cent of walking distances (30 ft) were very muddy. The normal time for walking in irrigated land is, amongst others, affected by type of crop, height of crop, wind velocity, conditions of soil surface due to cohesion force between saturated soil and feet of labourers, irregularities causing small ponds containing water, and also streams and other water-logged conditions.



#### 4.2.2. Equipment Factors

The size, weight and length of pipes affect S.T.V. The following are those which have a major influence on time requirements,

##### 4.2.2.1. Number of cycles.

The number of cycles for moving pipes depends on:\*

1. length of each piece,
2. number carried at one time,

The following table and graphs show the relationship. It should be noticed that the number of cycles are decreased with increasing the length of pipes.

Table 13. Number of Cycles and Length of Pipes in 1/4 Mile System

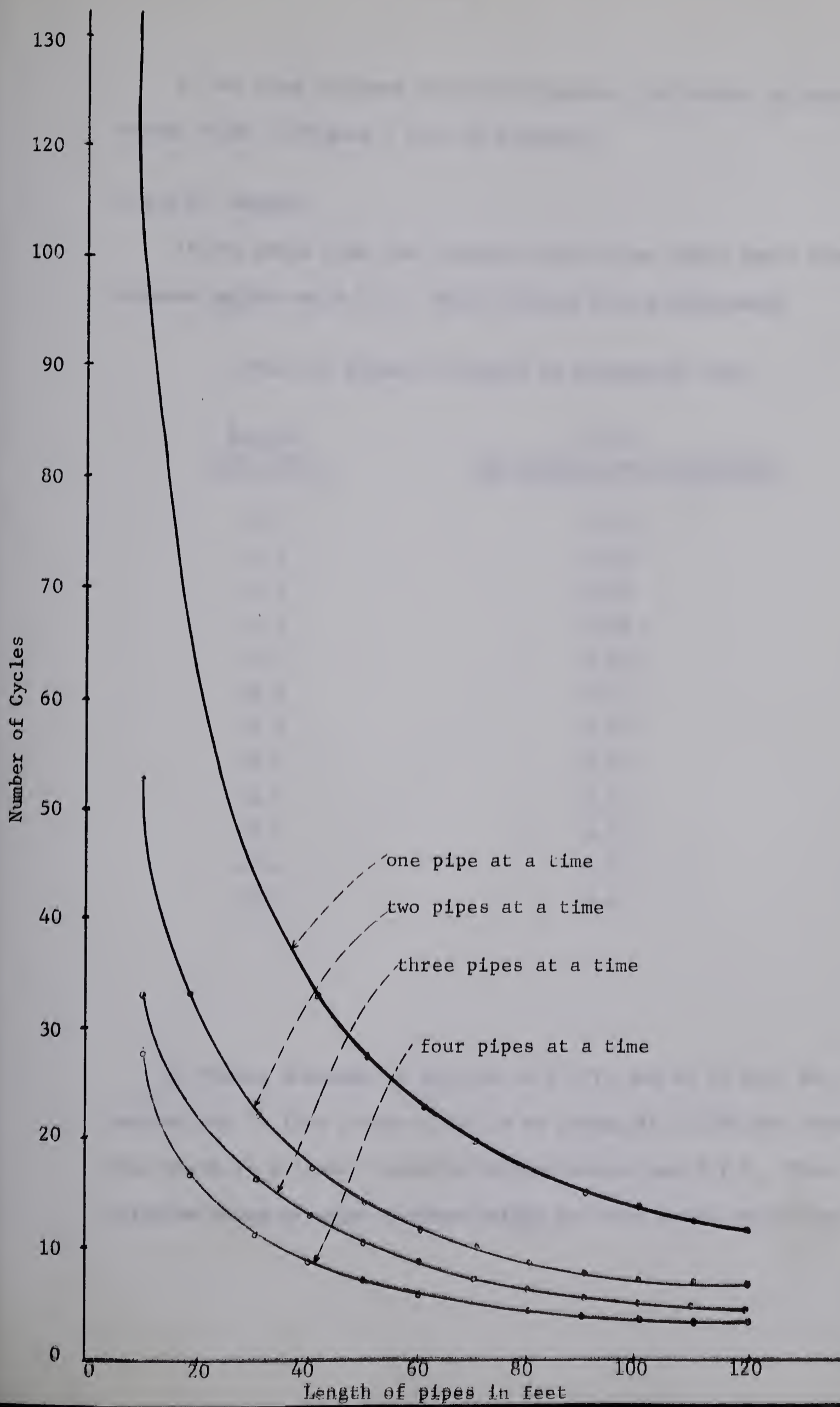
Length of Pipe	One at One time	Two at One time	Three at One time	Four at One time
10	132	66	44	33
20	66	33	22	17
30	44	22	15	11
40	33	17	11	9
50	26	14	9	9
60	22	11	8	6
70	19	10	7	5
80	17	9	6	5
90	15	8	5	4
100	14	7	5	4
110	13	7	4	3
120	11	6	4	3

Note: Number of cycles has been rounded off to the next whole number since fractions of cycles are not realistic.

\*A cycle consists of picking up, carrying, connecting the pipe or pipes and walking back to old set.



Figure 7. Cycle and length of Pipes.





If the size of pipes is plotted against the number of cycles, the curves shown in Figure 7 will be produced:

#### 4.2.2.2. Weight

It was noted from the collated times that there was a relationship between weight and S.T.V. Table 14 shows this relationship.

Table 14. Effect of Weight on Connection Time.

<u>Weight</u> <u>(In lbs)</u>	<u>S.T.V.</u> <u>(In minutes for connection)</u>
0.9	0.04
1.2	0.04
1.8	0.04
2.1	0.04
4.6	0.04
13.8	0.10
17.0	0.10
20.7	0.12
26.8	0.15
40.1	0.21
40.4	0.25
85.0	0.43

In Figure 8 weight is plotted vs S.T.V. and as it will be noticed, up to five pounds there is no change in S.T.V. but after that there is a linear relation between weight and S.T.V. This relation seems to exist between weight and some other operations.



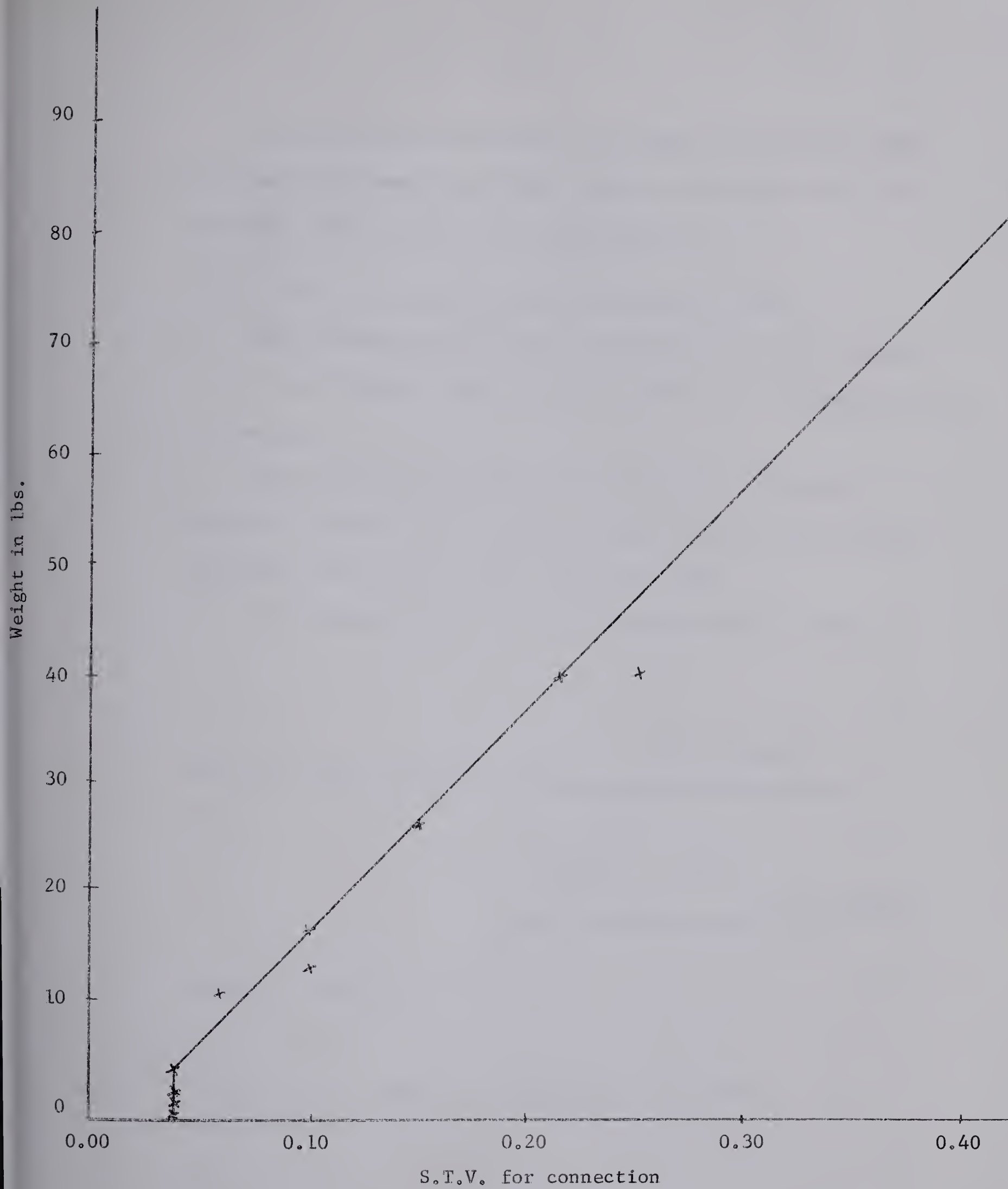


Figure 8. Effect of Weight



As was previously mentioned the weight of four pipes limits the number that may be carried. Aluminum pipe weighs 29.83 lb. per forty feet length of four inch diameter.

#### 4.2.3. Relation between Distances and Size of Pipes

The distances for carrying or walking in each cycle depends on the size of pipe, number of pipes carried at a time, and the method of movement.

The following tables show these distances. It should be noted that only the first walking distance varies for one and two operators, and all others will remain the same.

The following figure shows the notations used in tables.

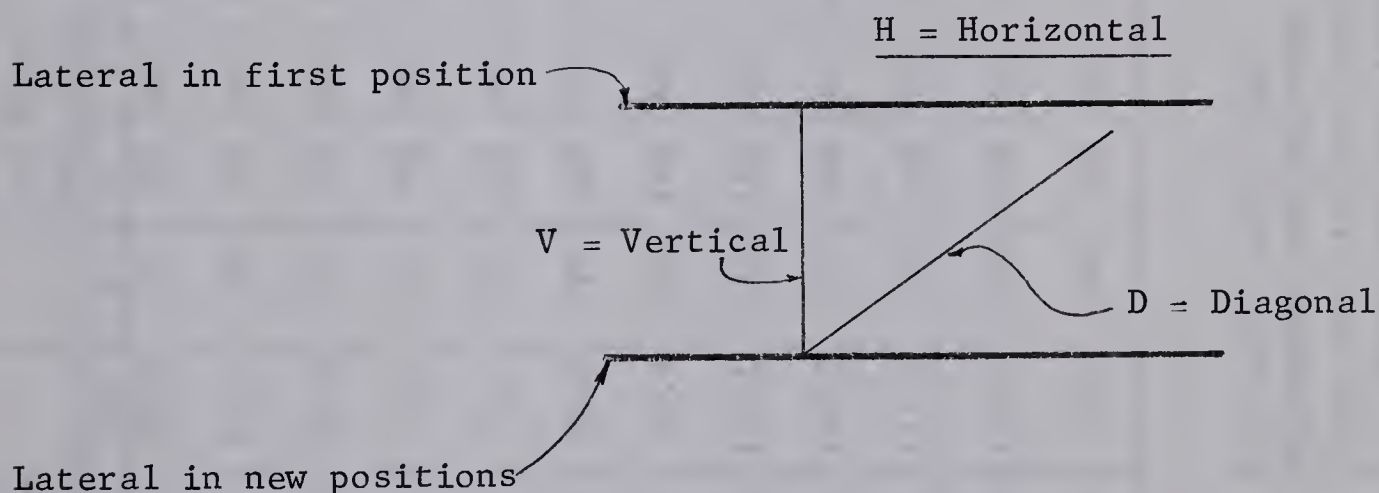


Figure 9. Directions of Distances.



Table 15. Relation Between Distances and Size of Pipes For One Operator.

Size of Pipe In Feet	Distance In Feet															
	One Pipe Each Time				Two Pipes Each Time				Three Pipes Each Time				Four Pipes Each Time			
	F	H	V	D*	F	H	V	D	F	H	V	D	F	H	V	D
10	5	0	60	60.8	15	20	60	63.2	25	40	60	67.0	35	60	60	72.0
20	10	0	60	63.2	30	40	60	92.0	50	80	60	84.8	70	120	60	100.0
30	15	0	60	67.0	45	60	60	84.8	75	120	60	108.2	105	180	60	134.0
40	20	0	60	72.0	60	80	60	100.0	100	160	60	134.0	140	240	60	171.0
50	25	0	60	78.1	75	100	60	116.2	125	200	60	161.0	175	300	60	209.0
60	30	0	60	84.8	90	120	60	134.0	150	240	60	189.5	210	360	60	248.0
70	35	0	60	92.1	105	140	60	152.3	175	280	60	218.0	245	420	60	303.0
80	40	0	60	100.0	120	160	60	171.0	200	320	60	248.0	280	480	60	325.0
90	45	0	60	108.2	135	180	60	189.5	225	360	60	276.1	315	540	60	368.0
100	50	0	60	116.2	150	200	60	209.0	250	400	60	306.0	350	600	60	404.1
110	55	0	60	125.2	165	220	60	228.0	275	440	60	335.8	385	660	60	444.0
120	60	0	60	134.0	180	240	60	248.0	300	480	60	369.2	420	720	60	483.2

\*Unloaded.

- Note: 1. All units are in feet.  
2. Distances are for each cycle  
3. Pipes are aluminum four inches in diameter.  
4. F - First move not loaded.  
5. Abbreviations are: H=horizontal distances (parallel to lateral pipes)  
V=vertical distances (perpendicular to lateral pipes)  
D=diagonal distances  
F=first move



Table 16. Relation between Distances and Size of Pipes for Two Men.

Distance In Feet																		
Size of Pipe In Feet	One Pipe Each Time				Two Pipes Each Time				Three Pipes Each Time				Four Pipes Each Time					
	F	H	V	D	F		H	V	D	F		H	V	D				
					F					F								
					1	2				1	2							
10	10	0	60	60.8	10	20	20	60	63.2	20	30	40	60	67.0	30	40	60	72.0
20	20	0	60	63.2	20	40	40	60	78.0	40	60	80	60	84.8	60	80	60	100.0
30	30	0	60	67.0	30	60	60	60	84.0	60	90	120	60	108.2	90	180	60	134.0
40	40	0	60	72.0	40	80	80	60	100.0	80	120	160	60	134.0	120	160	60	171.0
50	50	0	60	78.1	50	100	100	60	116.2	100	150	200	60	161.0	150	200	60	209.0
60	60	0	60	84.8	60	120	120	60	134.0	120	180	240	60	189.0	180	240	60	248.0
70	70	0	60	92.0	70	140	140	60	152.3	140	210	280	60	218.0	210	280	60	303.0
80	80	0	60	100.0	80	160	160	60	171.0	160	240	320	60	248.0	240	320	60	325.0
90	90	0	60	108.2	90	180	180	60	189.5	180	290	360	60	276.0	290	360	60	368.0
100	100	0	60	116.2	100	200	200	60	209.0	200	300	400	60	306.0	300	400	60	404.0
110	110	0	60	125.2	110	220	220	60	228.0	220	330	440	60	335.8	330	440	60	444.0
120	120	0	60	134.0	120	240	240	60	248.0	240	360	480	60	369.2	360	480	60	482.9

Note: 1. Pipes are aluminum four inches in diameter.

2. Abbreviations are: H = horizontal distance

V = vertical distance

D = diagonal distance

F = first move

3. Distance F has been shown for man No. 1 and No. 2. In the case of one pipe at one time there is no first distance for operator No. 1

4. All distances other than F are walked by both operators.



Because the choice between one and two workers is of considerable practical importance, a special study was conducted in a storage yard with skilled operators. The object was to validate the times for one or two men with laboratory conditions. These are described in Table 17.

Table 17. S.T.V. for One and Two Operators.

Elements (1)	S.T.V. One Operator (2)	S.T.V. Two Operators (3)	Number of Observations (4)	Decrease* Percentage (5)
Pick up	0.06	0.02	10	67
Carry Pipe	0.58	0.28	20	52
Laydown	0.06	0.02	18	67
Connect	0.085	0.019	10	78

As it can be seen, by increasing the number of operators, the S.T.V. for all operations decreases. The above relation has been used to calculate S.T.V. for two operators.

#### 4.2.4. Determination of S.T.V. for different sizes and numbers of operators.

The following table is of the average S.T.V. for elements timed in a range of between 1300 to 1600 observations. It will be shown in Section 3 that this provides 95 confidence band within one hundred cases.

The other S.T.V. for various conditions could be determined from actual S.T.V. by using the following tables and formulae, that were obtained during this study.

\* Column (2) is 100%



Table 18. S.T.V. for the Main Elements in Lateral Pipe Moving with One Operator.

Elements	40 Ft. length	20 Ft. length	10 Ft. Length
Walking	0.84/100'	0.84/100'	0.84/100'
Carrying	0.93/100'	0.49/60'	0.45/60'
Pick-up	0.48	0.18	0.16
Connection	0.17	0.045	0.04
Lay-down	0.05	0.022	0.02

Note: 1. Above S.T.V. are averages for one operator and aluminum pipes of 40 feet in length and 4 inches in diameter which weigh 29.8 lbs.

2. All S.T.V. are in minutes.
3. Standard time values for 40' and 20' lengths have been observed in both cases (one or two operators) and the relation between them has been used for calculations of S.T.V.
4. There was no possibility to observe some operations of other sizes of pipes because those sizes of pipes are not used and some of the sizes could not be found by the following assumption:
  - a) Only S.T.V. for 20' and 40' were used as a datum for calculation.
  - b) For each 10 feet increase in length the reference S.T.V. is 4 per cent for increase of weight, and five per cent for tediousness.<sup>22</sup> The 4 per cent increase related to weight is derived from the curve showing relation between S.T.V. and weight which has --- resulted from actual observations. Therefore, the effect of a ten feet increase, is a total increase of 9 per cent of the S.T.V. that has been added to S.T.V. for each ten feet of increase in length.
5. The S.T.V. for two operators have been calculated on the basis of relation obtained from observations recorded under validation conditions.
6. Effect of various factors such as wind, crops and soil have been included by averaging for basic references.

<sup>22</sup> International Labour Office, Op cit.,



#### 4.3. The Identification of Formulae Governing the Labour Requirement for Moving Pipes.

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Having acquired 1600 times for each element and having plotted these on graphs in Fig. 10, 11 which revealed the relationships for various factors present during the observations, it was possible to synthesize the expected time of each method under specified conditions. It was found that no simple formulae could be used to express the calculations of the expected times for a given method. Much study and analysis of graphs of synthesized times was conducted until a relationship was identified.

By plotting S.T.V. obtained in these studies and the length of pipe with respect to the various methods of moving, the curves in Figure 10 were produced, showing that:

1. the proposed method curve as it shows in Figure 10 requires less time than for other methods under study.
2. changing pipes with the present methods and using two operators is not economical,
3. it shows also, that an increase in the length of pipes decreases the S.T.V. and consequently decreases the cost of labour for one operator.

##### 4.3.2. Formulae construction from S.T.V. Graphs.

The curves produced from Tables of S.T.V. are of various shapes. For practical purposes it is not necessary to find precise equations, for all these curves, but because the proposed method is of importance,



# LEGEND

Present Methods

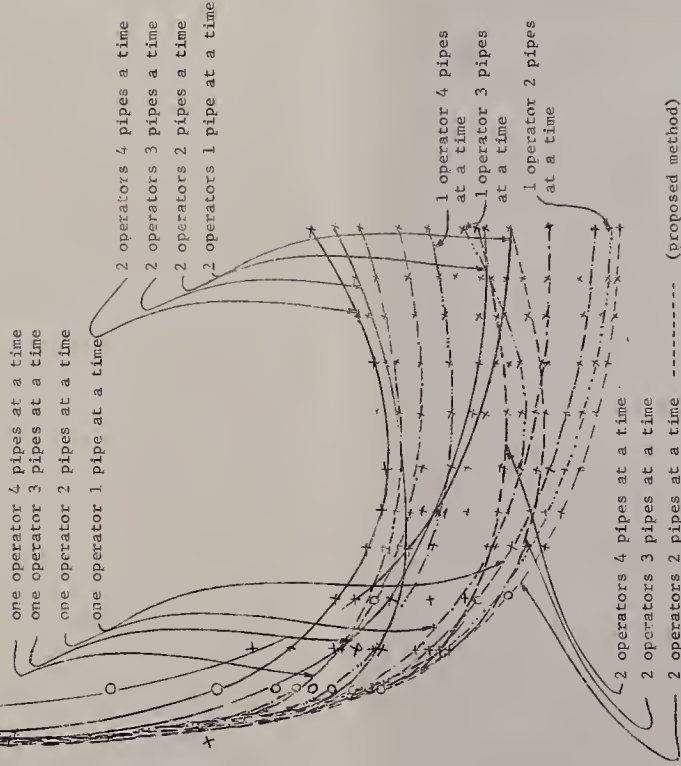
New Methods

Measured Times

Calculated Times

o o o

x x x x



20 40 60 80 100 120  
 Length of pipe in feet

Figure 10. Present and New Methods of Moving Sets.



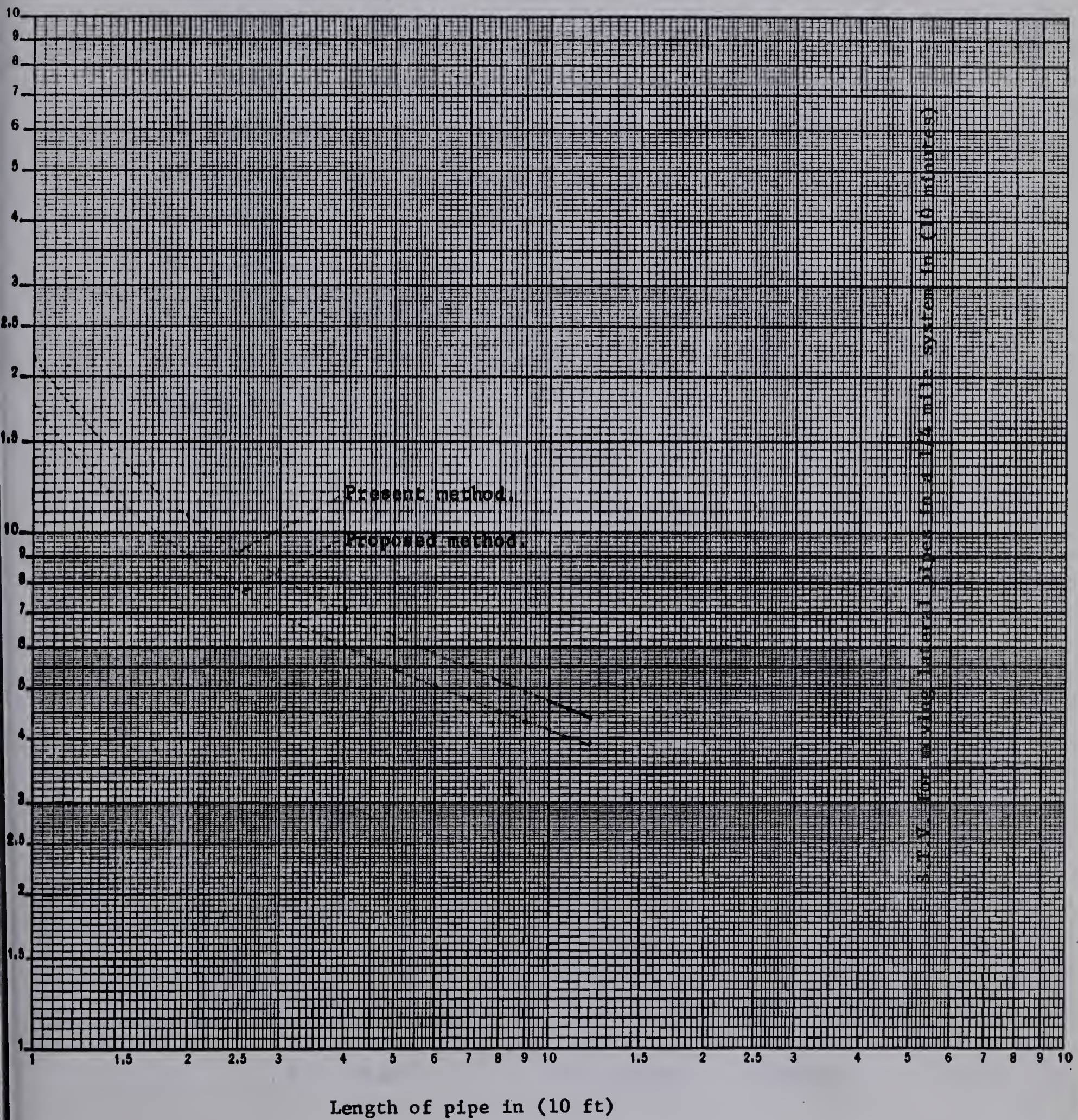


Figure 11. S.T.V. for present and proposed methods.



the general empirical formula has been found by the least square method for it. This could be applied for other curves by changing the constants. The general formula is:  $x = S + Ty + Uy^2$

First the results were plotted on linear graph paper. Then the curves were plotted on semi-logarithmic and logarithmic paper and the curves shown in Figures 11 and 12 were produced. By carefully testing the many equations, a reasonable fit was obtained. The formulae were constructed by choosing three points on the curve and finding the parameters by matrix formation, and then tracing along the curve and finally testing the equation, for the proposed method.

$$\begin{bmatrix} 42 \\ 39 \\ 38 \end{bmatrix} \begin{bmatrix} 1764 \\ 1521 \\ 1444 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} \begin{bmatrix} T \\ U \\ S \end{bmatrix} = \begin{bmatrix} 100 \\ 110 \\ 120 \end{bmatrix}$$

$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} \begin{bmatrix} 42 \\ -117 \\ -152 \end{bmatrix} \begin{bmatrix} 0.0238 \\ 0.0718 \\ 0.0936 \end{bmatrix} \begin{bmatrix} T \\ U \\ S \end{bmatrix} = \begin{bmatrix} 2.38 \\ 17.18 \\ 19.36 \end{bmatrix}$$

$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix} \begin{bmatrix} 0.0496 \\ -0.000614 \\ 0.187 \end{bmatrix} \begin{bmatrix} T \\ U \\ S \end{bmatrix} = \begin{bmatrix} 8.554 \\ -0.147 \\ 41.704 \end{bmatrix}$$

$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} \begin{bmatrix} T \\ U \\ S \end{bmatrix} = \begin{bmatrix} -2.5068 \\ -0.01 \\ 223 \end{bmatrix}$$

$$T = -2.51$$

$$U = -0.01$$

$$S = 223$$



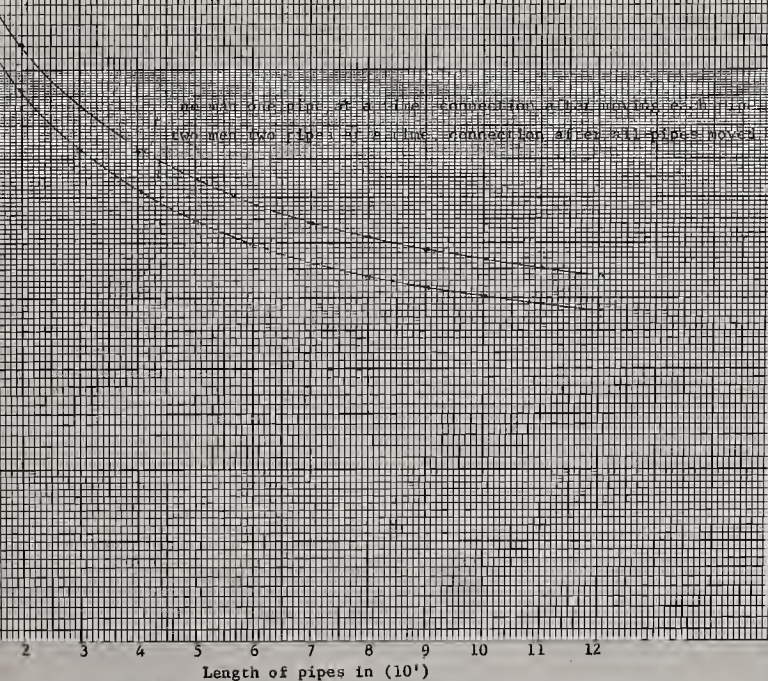


Figure 12. Present and proposed methods.



If the curve with the above parameters is traced, T will be only slightly changed.

The parameter of T for eight various parts gives an average close to Napierian number e when the equation for this curve is for a length between 30' and 120'.

$$X = 223 - 2.67y - 0.01y^2 \quad (14)$$

For length 20' to 30' it is:

$$X = 223 - 1.83y - 0.01y^2 \quad (15)$$

and for length below 20' it is:

$$X = 223 + 0.499y - 0.01y^2 \quad (16)$$

Where: X = length of each pipe in feet  
y = S.T.M. in minutes (Man-minutes).



#### 4.4. Labour Requirment in Irrigation Systems.

##### 4.4.1. Sprinklers

Labour requirement for three sprinkler systems and two gravity irrigation methods practiced generally in Alberta have been calculated.

##### 4.4.1.1. Hand Move.

Labour-hour required in sprinkler irrigation hand move consists of:

1. layout and gathering  $= \frac{117.19}{60} \times 4 = 7.81$  labour-hour for  
1/4 mile system,

2. changing sets  $= \frac{71.35}{60} = 1.18$  labour hours per set,

3. engine and pump services;

Stopping engines	0.23 S.T.V. per set	(These S.T.V. can be regarded as the equivalent of clock minute work and rest when totalled.)
Starting engines	0.34 S.T.V. per set	
Checking out	0.33 S.T.V. per set	
Priming	0.71 S.T.V. per set	
Opening-closing valve, other services	1.80 S.T.V. per set	
Clearing stream	1.50 S.T.V. per set	

TOTAL 4.91 S.T.V. for engine and pump set per set.

4. System cleaning = 33.8 S.T.V. per set

5. Power plant setting 240 S.T.V. for 1/4 mile.

Therefore:

a) lay out and gathering = 5.40 labour-hours per 40 acres per season.



b) changing set, three irrigations per season	=	78.60 labour-hours/40 acres/season
c) engine, pump services	=	5.40 labour-hours/40 acres/season
d) system washing and clearing	=	22.21 labour-hours/40 acres/season
e) power plant setting	=	4.00 labour-hours/40 acres/season
f) power plant moving	=	4.00 labour-hours/40 acres/season
g) miscellaneous	=	10.00 labour-hours/40 acres/season
TOTAL	=	135.02 labour-hours/40 acres/season

Labour-hours required in sprinklers hand move per acre per irrigation is 1.13 labour-hours.

- Note:
1. Washing and cleaning system once a day.
  2. Pump and power services once per set.
  3. The above figures are averages of S.T.V. obtained from field operations.
  4. Supervision time is not included.
  5. For larger areas the labour-hour requirement seems to be slightly lower than 1.13 per acre per irrigation because some operations will remain the same in both areas such as power and pump services or layout etc.
  6. These data are for the present equipment used in the area under study.

#### 4.4.1.2. Wheel Move.

In this system the requirement of labour consists of:

##### 1. preparation for moving

a) closing valve	0.59 minutes per set
b) disconnection of first pipe	0.47 minutes per set
c) moving ring	0.49 minutes per set
d) carrying the support and installation	1.09 minutes per set
e) valve connection	0.33 minutes per set
f) walking back and forth	1.00 minutes per set



2.	walk to the mover engine	9.00 minutes per set
3.	waiting for drainage of pipe	33.03 minutes per set
4.	moving lateral pipes	
	a) take off the cover	0.20 minutes per set
	b) start	0.36 minutes per set
	c) moving time	3.15 minutes per set
	d) stop engine	0.23 minutes per set
	e) replace the cover	0.14 minutes per set
5.	walking back	9.00 minutes per set
6.	power unit and pump services (same as in hand move)	4.91 minutes per set
7.	miscellaneous	3.00 minutes per set
8.	connection to main pipe	
	a) moving the first pipe	0.36 minutes per set
	b) connection	0.10 minutes per set
	c) tightening with a ring	0.53 minutes per set
	d) opening the valve	0.40 minutes per set
9.	waiting to check	3.00 minutes per set

---

TOTAL 66.47 minutes per set

Then the labour-hour requirement for each irrigation is:

$$\frac{66.47}{60} = 1.108 \text{ hour}$$

1.108 hour per set per irrigation

Acreage covered per set = 3.62 acres.

$$1.108 \div 3.62 = 0.31 \text{ labour-hour/acre/irrigation.}$$

Note: 1. The system did not have drainage valves.

2. The S.T.V. are for present systems in practice.

#### 4.4.1.2. Valley Move.

In this system labour is required for:

- |    |                               |                            |
|----|-------------------------------|----------------------------|
| 1. | first moving systems to field |                            |
|    | Average                       | 16.00 hours/set/irrigation |



2. checking for unexpected happenings	
20 minutes each time, three times	
a day per irrigation, 5 x 1 =	5.00 hours/set/irrigation
3. cleaning and other services	1.00 hours/set/irrigation
TOTAL	22.00 hours/set/irrigation

Coverage per set = 130 acres.

$$\frac{22}{130} = 0.17 \text{ labour-hours/acre/irrigation}$$

Note: 1. These figures are the results of observations of two Valley systems in Bow Island.

#### 4.4.2. Surface Irrigation Labour Hour Requirement

Two systems of surface irrigation have been studied.

1. Flooding.
2. Use of Gated Pipes.

The following discussions are the result of studies carried for this purpose.

##### 4.4.2.1. Flooding

Average labour requirement in this method consists of:

1. Setting canvas
  - a) pick up canvas .60 minutes per set
  - b) passing a rod into canvas .98 minutes per set
  - c) carrying canvas to new position 1.44 minutes per set
  - d) lay it down in ditch 1.44 minutes per set
  - e) shovelling mud out 3.24 minutes per set
  - f) walking to old position 1.10 minutes per set
  - g) move out next canvas to permit water to flow 1.20 minutes per set
  - h) waiting for water to reach outlet pipe 1.40 minutes per set
  - j) put aside the canvas 2.50 minutes per set
  - k) shovelling 2.10 minutes per set



2. Inspection

a) walking	7.52 minutes per set
b) shovelling	30.00 minutes per set
c) inspection	10.00 minutes per set

3. Miscellaneous 30.10 minutes per set

TOTAL 93.62 minutes per set  
per irrigation.

Coverage per set = 0.48 acres.

then:

$$\frac{93.62}{60 \times 0.48} = 3.25 \text{ labour-hours per acre per irrigation}$$

4.4.2.2. Surface Irrigation by Gated Pipes.

Average labour-hours required for irrigation by gated pipe are:

1. Shovelling	20.00 minutes/set/irrigation
2. Walking	10.00 minutes/set/irrigation
3. Inspection	20.00 minutes/set/irrigation
4. Opening the orifices	9.50 minutes/set/irrigation
5. Closing orifices	10.30 minutes/set/irrigation

TOTAL 69.80 minutes/set/irrigation

Coverage per set:

Area of block 150' x 150' = 22,500 sq ft.

$$\frac{22,500}{43,560} = 0.516 \text{ acre per set.}$$

$$\frac{69.80}{0.516 \times 60} = 2.25 \text{ labour-hour per acre per irrigation.}$$



- Note: 1. The experiment took place on six farms for flooding and one far for gated pipe irrigation.
2. The above figures are averages of data obtained in various fields.
3. Preparation of main ditches and small ditches is not included here. They should be considered as a part of land preparation for irrigation with surface irrigation methods.
4. The time for carrying water in main ditches is excluded.
5. The crops were alfalfa, sugar beet, corn, potatoes, and wheat.

This study shows that labour-hour requirement varies from a minimum of 0.17 labour-hour per acre per irrigation for sprinkler irrigation by Valley system to a maximum of 3.25 labour-hour per acre per irrigation for flooding irrigation.

The following table shows the result of this study.

Table 19. Labour-requirement for Various Irrigation Methods.

System of Irrigation	Type	Crop	No. of farms	No. of observations	Average Labour-hour/acre/irrigation
Surface	Flooding	Alfalfa, wheat, sugar beet, corn, potato.	6	300	3.25*
	Gated pipe	Alfalfa, wheat, sugar beet, corn, potato.	1	89	2.25*
Sprinkler	Hand move	Flax, wheat, alfalfa, sugar beet, potato, beans	22	1400	0.91
	Wheel move	Wheat, flax	5	160	0.31
	Valley Move	Flax	2	48	0.17

\*Note: It is possible that too small a sample was taken to be typical as other studies show smaller data.



PART V  
PROPOSALS

The following are proposals developed during this study.

5.1. Method Design for Lateral Pipe Movement.

There are 384 possible various methods of moving lateral pipes in hand-move systems, taking into account permutations of the undernoted factors.

Description	Alternatives
1. Length of pipes from 10 ft to 120 ft length, (10' increment).	12
2. Number of pipes carried at a time: 4,3,2, or 1.	4
3. Number of operators: either one or two men in the team.	
4. The connection of pipes is possible after: a) either all pipes have been moved to new positions, or b) each pipe has reached its new position.	2
5. Starting: a) from main pipe, b) from end and connecting last pipe with a short flexible hose to main pipe.	2

Therefore the product of the alternatives is:

$$(12)(4)(2)(2)(2) = 384 \text{ possible methods of moving the pipe.}$$

By application of method study and use of network diagrams, the shortest practical and non-practical routes have been found.

The methods and tables and formulae are in Appendices C, D and E.







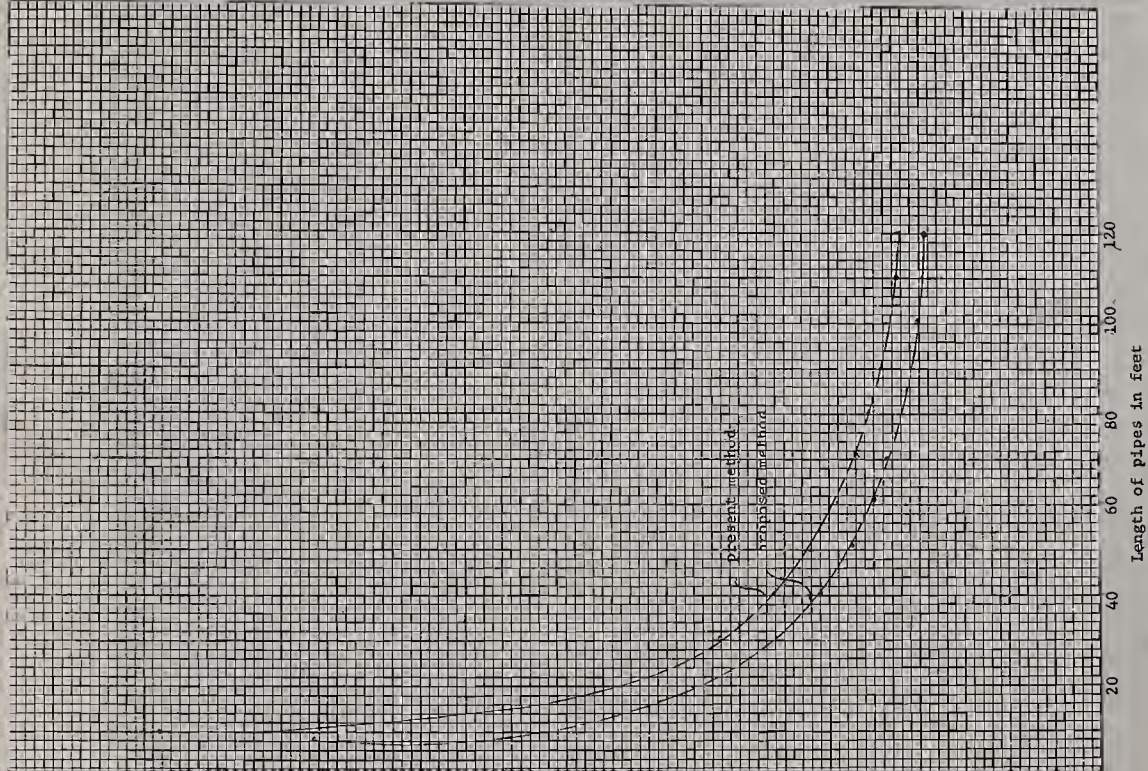


Figure 14. Present and Proposed Methods



## 5.2. Method Design for Lateral Pipe Layout

### 5.2.2. Lay out of pipe.

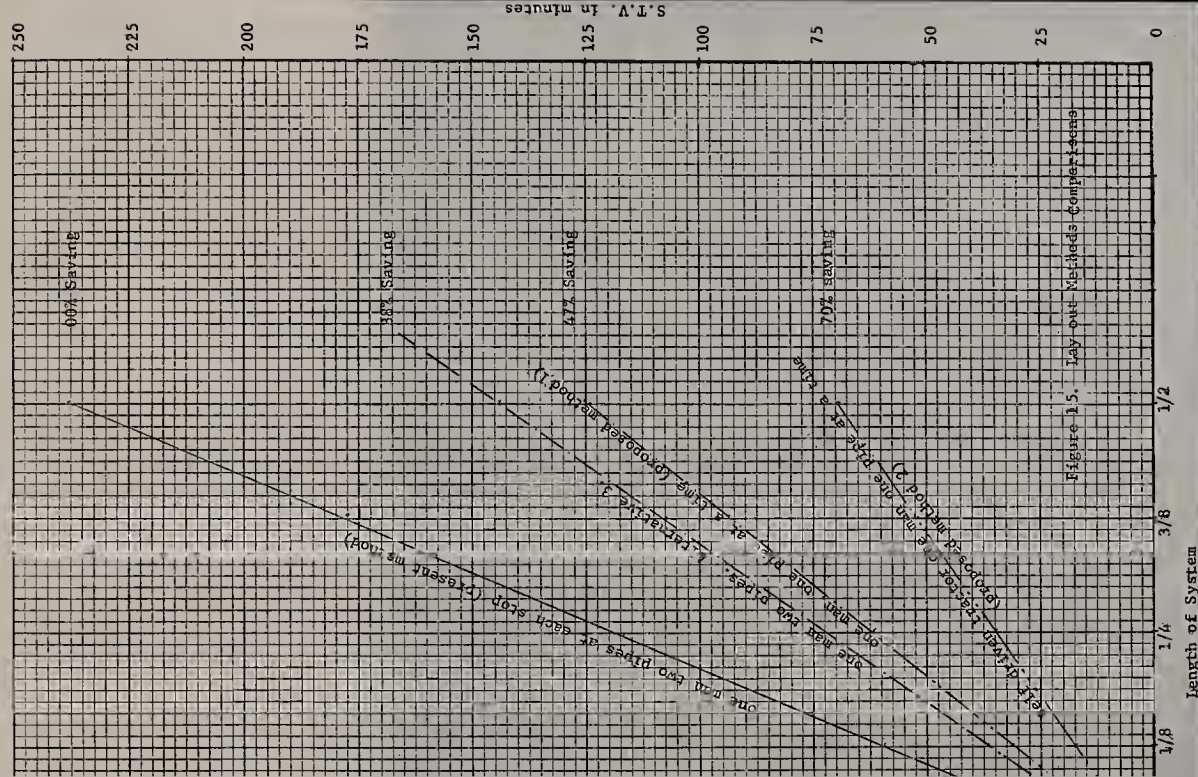
Several methods are used at present for the layout of pipes.

Here the purpose is not to describe all possible methods, but to compare one of the poorly designed typical methods which is practiced, with the new or proposed methods will be described. It should be noticed that all present methods are not as poorly managed as is the method described, but many are equally ineffective and wasteful.

Table 20. S.T.V. for layout of a 1/4 mile lateral pipe with different systems.

Alter-native	Method	T Driv- ing	T <sub>2</sub> Stop- ing	T <sub>3</sub> Pick- up	T <sub>4</sub> Carry- ing	T <sub>5</sub> Walk- ing	T <sub>6</sub> Conn- ection	T <sub>7</sub> Start- ing	TOTAL
1	One man present method	20.06	6.60	31.68	12.96	34.01	5.61	6.27	117.19
2	One man one pipe a time	20.06	13.20	15.84	1.21	1.11	5.61	5.61	62
3	One man two pipes a time	20.06	6.60	15.84	6.83	11.36	5.61	5.27	71.57
4	Automatic tractor- one pipe at a time	0	0	15.84	1.21	12.11	5.61	0	34.77





### Figure 15. Lay-out Methods Comparisons



In the lay out of alternative No. 2 and self driven tractor (alternative No. 4) the cost of labour is less while all other conditions are kept the same.

Labour wage has been assumed as \$1.00 per hour for all calculations.

Table 20 shows the S.T.V. for a 1/4 mile lateral pipe line layout. It could be noticed that alternative No. 4 is the quickest route for layout of these lateral pipes. In this method the tractor is driven by itself very slowly and there is a string connected to the switch and the trailer, where the tractor could be stopped immediately if it is desired. By this method most stopping, starting and driving time will be saved.

The second shortest procedure is the proposed method and is one man one pipe at a time. The pipes should be connected to the proper positions that they are carried to, as is seen in Figure 16. The trailer should be driven very close to the position that the pipes are to be set.

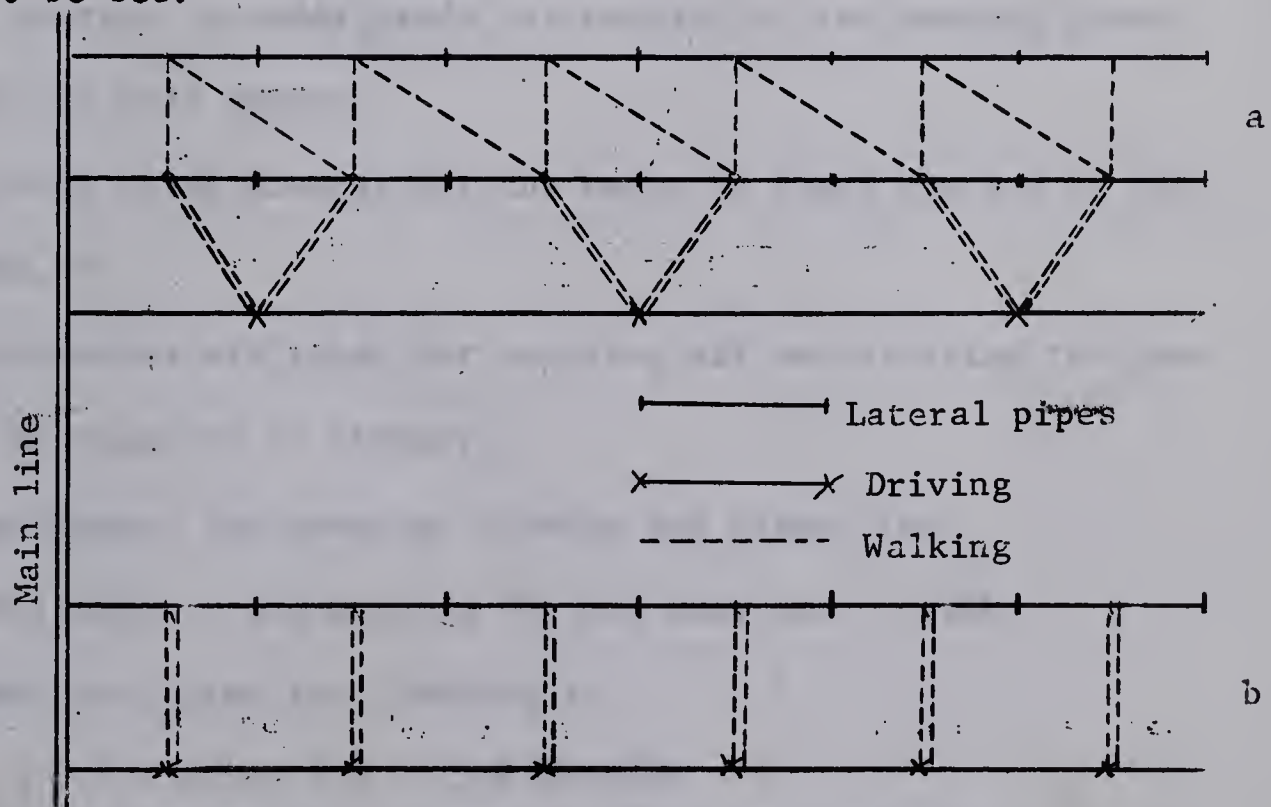


Figure 16. Present and Proposed Methods of Pipe Lay out.

- a) present method
- b) proposed method



### 5.3. Automatic End Plugs

The need for some remote controlled or automatic end plug was noted during the studies when it was observed that the operators walk 1/2 mile for each 1/4 mile set change. The end plug is used to allow water containing earth to be flushed out to avoid clogging the sprinkler jets.

Flushing the pipes is done by two operators: one of the operators waits until his partner has walked to the pump and started it. After the water has reached the end of the lateral pipes, and washed it, the operator at the end of the pipes signals, and the other operator at the pumps shuts the pump off. Then, after closing the end plug and signaling the other operator, he turns the pump on again. This operation, in a 1/4 mile system, takes at least:

1.  $(0.005)(1320) = 6.6$  minutes\*.

The average in muddy lands for walking to the pumping plant in a 1/4 mile system.

2. It takes three minutes for the water to reach the end of the pipes.\*\*

3. Two minutes are taken for shutting off and starting the pump and to regulate it (twice).

4. Two minutes for opening, closing and signalling.

$(0.005)(1320) = 6.6$  minutes for the next man to walk.

Thus the total time for flushing is

$$6.6 + 3.0 + 2.0 + 2.0 = 13.6 \text{ minutes}$$

\*For walking 100 ft the required time is 0.5 minutes.

\*\*Average velocity has been assumed about 7.3 feet per second.



Because two men were involved, then, the total man minutes is:

$$13.6 \times 2 = 27.2 \text{ minutes.}$$

By assuming one of the operators, after flushing the pipes, goes to do other jobs, the other operator still has to walk 1/4 mile, then:

$$5. \quad 0.50/100' (1320) = 6.6 \text{ minutes.}$$

Therefore: the man-time for flushing a 1/4 mile system is

$$27.2 + 6.6 = 33.8 \text{ minutes man-time.}$$

Then each time that the set is changed 33.8 minutes is going to be spent for washing the pipes, if flushing has to be done in each set changing for better operation of the system.

By installation of some kind of end-plugs that could be operated automatically under a range of pressure, the time for washing will be decreased only to the total of

$$3 + 2 = 5 \text{ minutes.}$$

Three minutes for the water to reach the end of the system and two minutes for flushing.

In other words, there has been 85% saving in washing time and 28% saving in the total time of moving and washing a 1/4 mile system, by using automatic end plugs.

Figure 17 shows an end-plug which can be used instead of the present installed end-plugs. This automatic end-plug is operated as a safety valve. The operating pressure which is generally at the end of the system is about 40 psi, acting upon the inside of valve v.



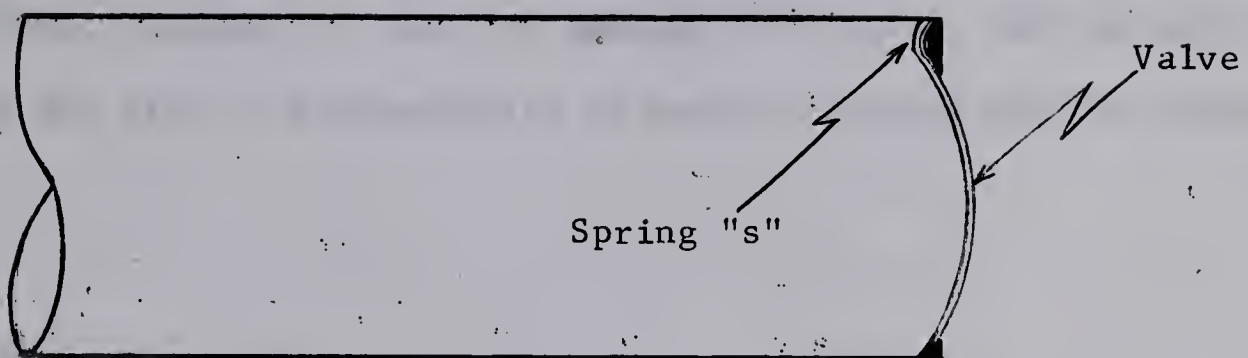


Figure 17. Automatic End Plug

The resistance of a spring "s" is designed such that under operating pressure (30 - 40 psi) the valve closes and as soon as the pressure drops the spring opens the valve and any water and silt or other contents, are flushed out through the opening. The change of pressure for this purpose could be done at the pumping plant.



This is one of the valves that could be used for this purpose.

By installation of this valve which from here on is called automatic end plug, there will not be any walking forward and back, and also it is possible to clean the pipes any time without stopping the pump. Because of ease of washing the system, with an automatic end plug, the possibility of nozzle clogging will be reduced.



#### 5.4. Automatic Drainage Valve

##### 5.4.1. Introduction

The roughness of lands is one of the most important factors causing extra time in picking up the lateral pipes. In lands with a slope in one direction, the normal time for the performance of this task was found to be 0.075 minutes, while in fields with various slopes and steepness in different directions this normal time is 0.660 minutes. In other words, roughness of the land causes delay related to the draining of pipes while they are inclined. The normal time for the same element in controlled conditions (not in field) is 0.036 minutes.\*

Due to this delay the observed data from different fields shows that normalized time for pick-up has been increased 8.8 times for draining the pipes. Because this element is repetitive in cycles of set moving in sprinkler irrigation by hand-move systems, then this delay costs many millions of dollars each year around the world. By studying situations and alternatives that are discussed in the following pages, installation of some kind of drainage valve in pipes is proposed. With draining the pipes, this unnecessary cost will be saved.

The valves could be made in such a way that they could be opened under low pressure and closed under higher pressure. The valve could be called an automatic drainage valve.

\*Note: Pipe is aluminum 40' in length by 4" in diameter and weighs 29.8 lbs.

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The cost of installation of such valves compared to the savings is negligible according to the inquiries made to some manufacturers.

The automatic drainage valve is not a device for drainage in hand-move sprinkler systems only, but also desirable in other systems such as wheel-move systems and Tri-matic systems.

The following discussion gives further details about these drainage valves.

About 25 per cent of the total time needed to move a lateral pipe 40 feet long by 4 inches in diameter (interior) is spent to drain the pipe before carrying it. If it is assumed that there are 33 pipes in a quarter mile system, then:

$$33 \times 0.22 = 7.26 \text{ minutes is required}$$

for draining the pipes for one set of a quarter mile system. To shorten or eliminate this time the following solutions were suggested:

1. Disconnection of pipes at the lower point.
2. Removing the end plugs if the land has a uniform grade.
3. Drainage of pipes by compressed air.
4. By the present method of moving.

All four methods will be discussed hereunder.

#### 5.4.1.1. Disconnection of Pipes at Lower Points

In most lands the topography is such that there are many low points and irregularities. Here, for the sake of argument, a field with only one low point, located along the lateral pipe

is chosen as an example. If a man wants to disconnect pipes for draining at that point, the normal time for walking is about

$$\frac{660 \times 2 \times 0.8}{100'} = 10.56 \text{ minutes}$$



If 10.56 minutes are spent for walking, and if the time for disconnection is added to this, it takes more than eleven minutes to make the disconnection, if it is assumed that the lowest point is located at the middle of the pipe's length. If this point is not located in the middle of the pipes, and if there is more than one low point as in undulating lands, the time for disconnection would be far more than eleven minutes. The purpose of this method is to shorten or to eliminate unnecessary work. As it can be seen this method is neither practical nor economical because there is no saving in time.

---

Note: 0.8 minute/100' seems very slow but this is because of mud and crops and other obstructions in farms. This standard time is calculated from 150 observations made prior to July 20, 1965.



#### 5.4.1.2. Removing End Plug

Removing the end plug could be practical for draining regardless of the time involved; only in lands with a continuous downward slope (in the direction of lateral pipes), which is rarely found.

Even with this ideal gradient it takes 22 minutes to remove the end plug. Therefore, the method is rejected for the same reason that the first method was, and it offers no advantage for the same reasons as stated in the first suggestion, 5.4.1.1.

#### 5.4.1.3. Drainage by Compressed Air

This method is not practical by reason of its two main disadvantages:

1. Additional equipment would have to be purchased.
2. There would be a high pressure loss because the pipes are not airtight.

Therefore this method is rejected, because of the expense involved.

#### 5.4.1.4. Present Method

Each pipe takes about 0.22 minutes to be drained by the present method. This figure by itself is not significant and reveals very little. However, considered as a repetitive element, the following rough figures show its importance.

1. Pipes are 40 feet in length and four inches in diameter and 33 pipes in a 1/4 mile system.
2. Three sets per day.
3. Irrigation season average May 15 to October 15 (150 days.)



4. Sprinkler irrigation land in Alberta is about 75,000 acres.
5. Each 1/4 mile system irrigates 1.8 acres per set.
6. Labour wage is about \$1.00 per hour.

Then:

$$0.22 \times 33 = 7.26 \text{ minutes per set for drainage}$$

$$75,000 \times 2 = 150,000 \text{ acres, total area irrigated per year.}$$

$$7.26 \div 1.8 = 4.00 \text{ minutes per acres for drainage.}$$

$$150,000 \times 4/60 \times 1.00 = \$10,000.$$

Thus, in Alberta \$10,000 are spent on pipes drainage in sprinkler systems. If this is to be considered in the U.S.A. and other parts of the world, many millions of dollars must be spent in this way.

After studying alternatives and application of methods engineering, the following method is suggested as a possible solution.

From Bernoulli's theorem (neglecting friction), the ideal velocity of efflux is  $v = \sqrt{2gh}$ . Since the ideal velocity, due to  $h$ , is the same as though the particles had fallen freely through the same height of  $h$ , then, in this case  $h$  varies from 0 to 3 inches. The total diameter of the pipes is four inches and if the orifice is located at one inch height from the bottom, then there would remain a maximum head about three inches. If the coefficient of discharge is considered,\*

---

\*It should be noticed that the discharge through the above orifice is a function of time, or of  $h$ . When  $h < r$ , then the valve operates as a weir. Here, because the required time for discharge does not need to be very accurate, it is assumed that the valve operates as an orifice.



then:

$$Q = C_d \sqrt{2gh}$$

where:

$$C_d = C_v \cdot C_c$$

Q = discharge cfs

a' = actual cross-sectional area in sq. ft.

v' = actual velocity ft/second

C<sub>c</sub> = coefficient of contraction (average 0.62)

C<sub>v</sub> = coefficient of velocity (average 0.98)

h = head in feet

C<sub>d</sub> = coefficient of discharge

g = acceleration due to gravity (32.2 ft/sec/sec)

y = If the coefficient of discharge determined by H.J. Bilton be chosen:\*

$$Q = 0.680 \sqrt{2gh} a'$$

If consideration is given to a very low head as compared to the orifice diameter, then the above formula will be slightly changed as follows.

In this special case suppose the orifice is located one inch from the bottom of the pipe, then the maximum head is three inches. When the pipe is full of water, to find the discharge through this orifice, an elementary strip is drawn horizontally across the orifice at a distance x from the center of the orifice. The small discharge through it is:

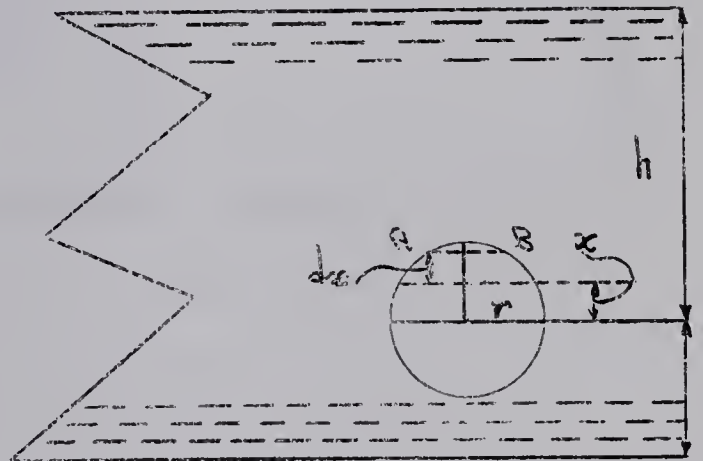


Figure 18. Discharge Through Orifice.

$$dQ = dA v = 2 \sqrt{r^2 - x^2} \cdot dx \cdot \sqrt{2g(h-x)}$$

because:

\*Note: Here the highest coefficient is chosen for the sake of argument, from Bilton tables: McDough's and Johnson's coefficient are slightly smaller (0.647).



Cross sectional area of this small section is:

$$dA = 2 \sqrt{r^2 - x^2} \cdot dx \text{ after integration}$$

$$r = \sqrt{2gh} \text{ and } h = (h-x)$$

$$dQ = dAv = 2 \sqrt{r^2 - x^2} \cdot dx \cdot \sqrt{2g(h-x)}$$

If  $x$  varies from  $-r$  to  $+r$ , the discharge of the entire orifice will lie in the integration of the above expression.

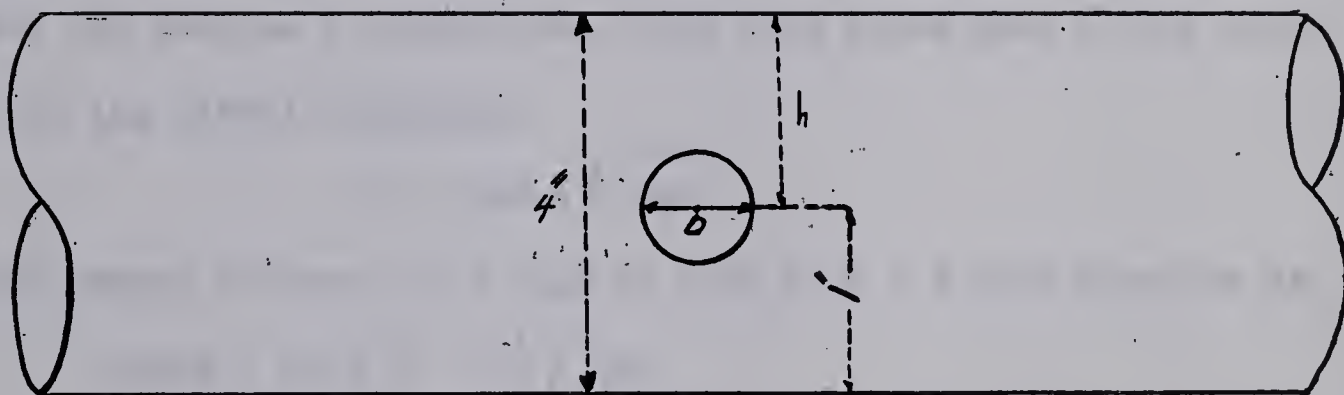


Figure 19. Drainage valve

$$Q = \int dAv = \int 2 \sqrt{r^2 - x^2} \cdot dx \cdot \sqrt{2g(h-x)}$$

If the term of  $(h-x)^{1/2}$  be expanded by binomial theorem, then:

$$(h-x)^{1/2} = h^{1/2} - \frac{h^{-1/2}x}{2} - \frac{h^{-3/2}x^2}{8} - \frac{h^{-5/2}x^3}{16} - \text{etc.....}$$

therefore:

$$dA = 2\sqrt{2g} \left[ (r^2 - x^2)^{1/2} h^{1/2} - \frac{(r^2 - x^2)^{1/2} x}{2h^{1/2}} - \frac{(r^2 - x^2)^{1/2} x^2}{8h^{3/2}} - \frac{(r^2 - x^2)^{1/2} x^3}{16h^{5/2}} - \text{etc.....} \right]$$



Then the result of integration:

$$Q = \pi r^2 \sqrt{2gh} \left( 1 - \frac{r^2}{32h^2} - \frac{5r^4}{1024h^4} - \frac{105r^6}{65537h^6} - \text{etc....} \right)$$

As it is seen the result is very close to the ideal discharge.

Because of the expression in parenthesis a unity minus

$$- \left( \frac{r^2}{32h^2} + \frac{5r^4}{1024h^4} + \frac{105r^6}{65537h^6} + \text{etc....} \right)$$

then this value is less than one. Therefore the discharge is less than that given by the ideal formula

$$Q = a \sqrt{2gh}$$

For our purpose a coefficient about 0.60 could give a very close result to the actual discharge.

$$A = 0.60 a \sqrt{2gh}$$

The amount of water in a pipe 40 feet with a 4 inch diameter is:

$$\text{Volume} = 40 \left( \frac{4}{2} \cdot \frac{1}{12} \right)^2 \pi$$

$$\text{Volume of water in one pipe} = (40) \cdot \frac{1}{36} \cdot (3.14)$$

$$\text{Therefore} = \frac{3.14}{9} \cdot 10 = \frac{31.4}{9} = 3.5 \text{ ft.}^3$$

The velocity could be calculated as follows:

$$\begin{aligned} \text{When } h &= 3'' & v &= C_v \sqrt{2gh} = C_v \sqrt{(64.4) \cdot \left(\frac{3}{12}\right)} \\ \text{then } v &= 4.013 \text{ fps.} \\ \text{When } h &= 0'' & v &= 0 \end{aligned}$$

Average of v would be about 2 fps.

Note:  $C_v$  is neglected here because it will be considered in the coefficient of discharge.



With this average velocity a valve could be connected with a simple scissors spring supporting this cap. When the nozzles are operating there is a head about 30 - 60 psi. The spring under high pressure will close the cap and under low pressure (when the main valve is closed) will automatically open the cap and the pipes will be drained. The following table shows the size of valves that could be used.

Table 21. Automatic Drainage Valve Size to Drain Pipes 40' x 4".

D Inch	r Inch	A Sq Ft	Q cfs	T in Minutes Time to drain 40' by 4" pipe	Pressure that valve opens (psi)
1/2	1/4	0.0018	.002160	27.01	0.144
3/4	1/8	0.0031	.003720	15.78	0.144
1	1/2	0.0054	.006480	9.00	0.144
1-1/2	3/4	0.0123	.014760	3.09	0.144

Note: To tabulate this table the following assumptions have been made.

1. Coefficient of discharge is chosen 0.60.
2. Bernoulli's formula (theorem) has been used.
3. The weight of one cubic foot of water is 62.335 lbs.
4. Abbreviations.
  - (a) D = diameter of orifice in inches
5. It was assumed that all pipes were horizontal.



- (b)  $r$  = radius of orifice in inches.
- (c)  $A$  = cross sectional area of orifice in sq ft.
- (d)  $Q$  = discharge of orifice in cfs.
- (e)  $t$  = time in minutes.

The above valve is only one of the many kinds of valves that could be used. In this thesis the purpose is not to design the best valve, but to examine the possibility of installing a drainage valve that reduces the cost of irrigation.



## EPILOGUE

"Where are they taking me? I like my sheep. I take them to the mountains before sunrise and bring them back to the tents after sunset. I love my quiet surroundings. All I can see is beautiful: those huge mountains, those light spots at night above me, that silvery river down there--everything is beautiful and a shepherd's life is very enjoyable. Then where do they want to send me? What is this school, and what can it do for me? Are there any sheep? Can I play my flute for them there as now I play every day for my sheep here?"

The above, and many other questions, were in my mind when I was told for the first time that I was to be sent to school.

I went to school, and a new world was introduced to me; a world of science and light. Not only could I better understand and enjoy those lights in the sky, and those huge mountains, but I could appreciate the value of that silvery river and its uses.

Now I would like to say words more strong and more meaningful than "thanks" to all my teachers, those who helped me and showed me the light of science.

I wish to express my most sincere gratitude to my adviser, Professor T.A. Preston, who guided me throughout the research and writing of this thesis. Without his guidance and interest, the field studies and the writing of this thesis would have been infinitely more difficult.



I would also like to express my deepest gratitude to my recent teachers, especially Mr. E. Rapp, Mr. D.G. Harrington, Mr. G.L. Steed, Dr. G.C. Russell, Dr. T.H. Anstey, and the many other engineers and research officers at the Lethbridge Research Station, for all their kindness and help during my research.

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Elements	Equipment Specification		Work Conditions					Time Study Data							Elements Break Points			
	Weight (lbs)	Size (in.)	Distance (ft)	Wind (mph)	Soil Surface Moisture	No. of Operators	Temp. °F	R.H. %	Avg. OT (min)	OR %	NT (min)	Rest Allowance %	Atmospheric Allowance %	Total Allowance %	S.T.M. (min)	Windchill Figure	Start	Finish
Pick up a Pipe	29.8	40'x4		8	Dry	1	70	25	0.04	133	0.052	26	3	23	0.062	10	Hands touch the pipe.	Pipe completely in hands.
Carry the Pipe	29.8	4x4	60	8	Dry	1	70	25	0.30	140	0.392	30	3	23	0.43	10	Start moving.	Stop moving at new position.
Connection of Pipe	29.8	4x4		8	Dry	1	70	25	0.05	130	0.065	20	3	23	0.075	10	One end of pipe connected to another pipe.	Hook is dropped.
Lay down a pipe	29.8	4x4		8	Dry	1	70	25	0.04	135	0.054	20	3	23	0.06	10	Pipe is laid down properly.	Pipe is completely released.
Disconnection of pipe.	29.8	4x4		8	Dry	1	70	25	0.04	120	0.048	15	3	18	0.13	10	Touching the pipe.	Two ends separated.
90° Elbow Pick up	1.5	2x2		8	Dry	1	70	25	0.022	120	0.024	11	3	14	0.03	10	Touching the elbow.	Elbow completely lifted up.
	4.8	4x4		8	Dry	1	70	25	0.02	120	0.024	11	3	14	0.03	10	Touching the elbow.	Elbow completely lifted up.
	8.1	6x6		8	Dry	1	70	25	0.02	120	0.034	11	3	14	0.03	10	Touching the elbow.	Elbow completely lifted up.
90° Elbow Connection	1.5	2x2		8	Dry	1	70	25	0.03	120	0.036	11	3	14	0.04	10	End of previous element.	Hands free.
	4.8	4x4		8	Dry	1	70	25	0.03	120	0.036	11	3	14	0.04	10	End of previous element.	Hands free.
	8.1	6x6		8	Dry	1	70	25	0.08	110	0.088	11	3	14	0.10	10	End of previous element.	Hands free.
45° Elbow Pick up	3.4	4x4		8	Dry	1	70	25	0.02	120	0.024	11	3	14	0.03	10	Touching elbow.	Elbow entirely lifted up.
	4.9	5x5		8	Dry	1	70	25	0.02	120	0.024	11	3	14	0.03	10	Touching elbow.	Elbow entirely lifted up.
	6.3	6x6		8	Dry	1	70	25	0.02	120	0.024	11	3	14	0.03	10	Touching elbow.	Elbow entirely lifted up.
45° Elbow Connection	3.4	4x4		8	Dry	1	70	25	0.03	120	0.036	11	3	14	0.04	10	Touching the pipe completely.	Releasing the pipe.
	4.9	5x6		8	Dry	1	70	25	0.03	120	0.036	11	3	14	0.04	10	Touching the pipe completely.	Releasing the pipe.
	6.3	6x6		8	Dry	1	70	25	0.06	110	0.066	11	3	14	0.05	10	Touching the pipe completely.	Releasing the pipe.
90° Elbow Disconnection	4.8	4x4		8	Dry	1	70	25	0.03	120	0.036	11	3	14	0.04	10	Touching the elbow.	Entirely disassembled.
45° Elbow Disconnection	3.4	4x4		8	Dry	1	70	25	0.03	120	0.036	11	3	14	0.04	10	Touching the elbow.	Entirely disassembled.



## S.T.M. FOR OPERATIONS IN SPRINKLER SYSTEMS. (Cont'd)

Elements	Equipment Specification		Work Conditions				Time Study Data						Elements Break Points				
	Weight (lbs)	Size (in.)	Wind (mph)	Soil Surface Moisture	No. of operators	Temp °F	R.H. %	Avg OT (min)	OR %	N.T. (min)	Rest Allowance %	Atmospheric Allowance %	Total Allowance %	S.T.M. (min)	Windchill Figure.	Start	Finish
Field tee pick up	2.1	2x2x2	8	Dry	1	70	25	0.02	120	0.024	11	3	14	0.03	10	Touching the tee.	Entire tee is lifted up.
	4.6	4x4x4	8	Dry	1	70	25	0.02	120	0.024	11	3	14	0.03	10	Touching the tee.	Entire tee is lifted up.
	9.1	6x6x6	8	Dry	1	70	25	0.02	120	0.024	11	3	14	0.03	10	Touching the tee.	Entire tee is lifted up.
Tee connection	2.1	2x2x2	8	Dry	1	70	25	0.03	120	0.036	11	3	14	0.04	10	Touching the pipe.	Assembly is finished.
	4.6	4x4x4	8	Dry	1	70	25	0.03	120	0.036	11	3	14	0.04	10	Touching the pipe.	Assembly is finished.
	9.1	6x6x6	8	Dry	1	70	25	0.02	120	0.036	11	3	14	0.04	10	Touching the pipe.	Assembly is finished.
Reducer pick up	1.8	3x2	8	Dry	1	70	25	0.02	120	0.024	11	3	14	0.03	10	Touching reducer.	Reducer entirely in hands.
	2.5	4x2	8	Dry	1	70	25	0.02	120	0.024	11	3	14	0.03	10	Touching reducer.	Reducer entirely in hands.
	3.3	5x4	8	Dry	1	70	25	0.02	120	0.024	11	3	14	0.03	10	Touching reducer.	Reducer entirely in hands.
Reducer connection	3.7	6x4	8	Dry	1	70	25	0.02	120	0.024	11	3	14	0.03	10	Touching reducer.	Reducer entirely in hands.
	4.1	6x5	8	Dry	1	70	25	0.02	120	0.024	11	3	14	0.03	10	Touching reducer.	Reducer entirely in hands.
	1.8	3x2	8	Dry	1	70	25	0.02	125	0.030	11	3	14	0.04	10	Reducer touches the pipe.	Assembling is finished.
End plug pick up	2.5	4x3	8	Dry	1	70	25	0.02	125	0.250	11	3	14	0.04	10	Reducer touches the pipe.	Assembling is finished.
	3.3	5x4	8	Dry	1	70	25	0.02	125	0.250	11	3	14	0.04	10	Reducer touches the pipe.	Assembling is finished.
	3.7	6x4	8	Dry	1	70	25	0.04	120	0.048	11	3	14	0.05	10	Touches the pipe.	Assembling is finished.
End plug connection	4.1	6x5	8	Dry	1	70	25	0.04	120	0.048	11	3	14	0.04	10	Touches the pipe.	Assembling is finished.
	0.9	2	8	Dry	1	70	25	0.02	120	0.024	11	3	14	0.03	10	Touching end plug.	End plug entirely in hands.
	1.2	3	8	Dry	1	70	25	0.02	120	0.024	11	3	14	0.03	10	Touching end plug.	End plug entirely in hands.
End plug connection	1.6	4	8	Dry	1	70	25	0.02	120	0.024	11	3	14	0.03	10	Touching end plug.	End plug entirely in hands.
	3.4	6	8	Dry	1	70	25	0.02	120	0.024	11	3	14	0.03	10	Touching end plug.	End plug entirely in hands.
	0.9	2	8	Dry	1	70	25	0.04	120	0.048	11	3	14	0.05	10	End plug touches the pipe.	End plug entirely assembled.
End plug connection	1.2	3	8	Dry	1	70	25	0.04	120	0.048	11	3	14	0.04	10	End plug touches the pipe.	End plug entirely assembled.
	1.6	4	8	Dry	1	70	25	0.04	120	0.048	11	3	14	0.05	10	End plug touches the pipe.	End plug entirely assembled.
	3.4	6	8	Dry	1	70	25	0.04	120	0.048	11	3	14	0.05	10	End plug touches the pipe.	End plug entirely assembled.

Finish

Start

Entire tee is lifted up.  
Entire tee is lifted up.  
Entire tee is lifted up.

Assembly is finished.  
Assembly is finished.  
Assembly is finished.

Reducer entirely in hands.  
Reducer entirely in hands.  
Reducer entirely in hands.  
Reducer entirely in hands.  
Reducer entirely in hands.

Assembling is finished.  
Assembling is finished.  
Assembling is finished.  
Assembling is finished.  
Assembling is finished.

End plug entirely in hands.  
End plug entirely in hands.  
End plug entirely in hands.  
End plug entirely in hands.

End plug entirely assembled.  
End plug entirely assembled.  
End plug entirely assembled.  
End plug entirely assembled.

Touching the tee.  
Touching the tee.  
Touching the tee.

Touching the pipe.  
Touching the pipe.  
Touching the pipe.

Touching reducer.  
Touching reducer.  
Touching reducer.  
Touching reducer.  
Touching reducer.

Reducer touches the pipe.  
Reducer touches the pipe.  
Reducer touches the pipe.  
Touches the pipe.  
Touches the pipe.

Touching end plug.  
Touching end plug.  
Touching end plug.  
Touching end plug.

End plug touches the pipe.  
End plug touches the pipe.  
End plug touches the pipe.  
End plug touches the pipe.



S.T.M. FOR OPERATIONS IN SPRINKLER SYSTEMS. (Cont'd)

Elements	Equipment Specification		Work Conditions				Time Study Data							Elements Break Points			
	Weight (lbs)	Size (in)	Wind (mph)	Soil Surface Moisture	No. of operators	Temp F°	R.H. %	Avg OT (min)	OR %	N.T. (min)	Rest Allowance %	Atmospheric Allowance %	Total Allowance %	S.T.M. (min)	Windchill Figure	Start	Finish
Flushing end Plug Pick up	1.6	2	8	Dry	1	70	25	0.01	125	0.013	11	3	14	0.02	10	Touching end plug.	End plug entirely in hands.
	2.0	3	8	Dry	1	70	25	0.01	125	0.013	11	3	14	0.02	10	Touching end plug.	End plug entirely in hands.
	2.6	4	8	Dry	1	70	25	0.02	120	0.024	11	3	14	0.03	10	Touching end plug.	End plug entirely in hands.
	3.2	5	8	Dry	1	70	25	0.02	120	0.024	11	3	14	0.03	10	Touching end plug.	End plug entirely in hands.
	3.6	6	8	Dry	1	70	25	0.02	120	0.024	11	3	14	0.03	10	Touching end plug.	End plug entirely in hands.
Flushing end plug connection	1.6	2	8	Dry	1	70	25	0.04	120	0.048	11	3	14	0.05	10	End plug touches the pipe.	Assembling is finished.
	2.0	3	8	Dry	1	70	25	0.04	120	0.048	11	3	14	0.05	10	End plug touches the pipe.	Assembling is finished.
	2.6	4	8	Dry	1	70	25	0.04	120	0.048	11	3	14	0.05	10	End plug touches the pipe.	Assembling is finished.
	3.2	5	8	Dry	1	70	25	0.04	120	0.048	11	3	14	0.05	10	End plug touches the pipe.	Assembling is finished.
	3.6	6	8	Dry	1	70	25	0.04	120	0.048	11	3	14	0.05	10	End plug touches the pipe.	Assembling is finished.
Flushing end plug disconnection	2.6	4	8	Dry	1	70	25	0.05	120	0.060	11	3	14	0.07	10	Touching the end plug.	Disassembling is finished.
Tee disconnection	4.6	4x4x4	8	Dry	1	70	25	0.04	120	0.048	11	3	14	0.05	10	Touching the tee.	Disassembling is finished.
Reducer disconnection	3.3	5x4	8	Dry	1	70	25	0.04	120	0.048	11	3	14	0.05	10	Touching the reducer.	Disassembling is finished.
End plug disconnection	1.6	4	8	Dry	1	70	25	0.03	120	0.036	11	3	14	0.04	10	Touching the end plug.	Disassembling is finished.
Increasor disconnection	3.4	4x5	8	Dry	1	70	25	0.03	120	0.036	11	3	14	0.04	10	Touching the increasor.	Disassembling is finished.
Increasor Pick up	0.9	1-1/2, 2	8	Dry	1	70	25	0.02	120	0.024	11	3	14	0.03	10	Touching the increasor.	Entirely in hands.
	1.5	1-1/2, 3	8	Dry	1	70	25	0.02	120	0.024	11	3	14	0.03	10	Touching the increasor.	Entirely in hands.
	3.4	4x5	8	Dry	1	70	25	0.02	120	0.024	11	3	14	0.03	10	Touching the increasor.	Entirely in hands.
	4.4	4x6	8	Dry	1	70	25	0.02	120	0.024	11	3	14	0.03	10	Touching the increasor.	Entirely in hands.
	4.7	5x6	8	Dry	1	70	25	0.02	120	0.024	11	3	14	0.03	10	Touching the increasor.	Entirely in hands.
Increasor connection	0.9	1-1/2x2	8	Dry	1	70	25	0.03	120	0.036	11	3	14	0.04	10	Touches the pipe.	Connection is finished.
	1.5	1-1/2x3	8	Dry	1	70	25	0.03	120	0.036	11	3	14	0.04	10	Touches the pipe.	Connection is finished.
	3.4	4x5	8	Dry	1	70	25	0.04	120	0.048	11	3	14	0.05	10	Touches the pipe.	Connection is finished.



## S.T.M. FOR OPERATIONS IN SPRINKLER SYSTEMS. (Cont'd)

Elements	Equipment Specification		Work Conditions							Time Study Data							Elements Break Points	
	Weight (lbs)	Size (in)	Distance (ft)	Wind (mph)	Soil Surface Moisture	No. of operators	Temp °F	R.H. %	Avg OT (min)	OR %	N.T. (min)	Rest Allowance %	Atmospheric Allowance %	Total Allowance %	S.T.M. (min)	Windmill Figure	Start	Finish
Increaseor Connection	4.4	4x6		8	Dry	1	70	25	0.04	120	0.048	11	3	14	0.05	10	Touching the Pipe.	Connection is finished.
Riser Connection	4.7	5x6		8	Dry	1	70	25	0.06	120	0.072	11	3	14	0.08	10	Touching the Pipe.	Connection is finished.
Riser Disconnection		10x1		9	Dry	1	70	25	0.29	115	0.334	11	3	14	0.38	10	Riser touches Pipe.	Connection is finished.
Tee Valve Connection	8.0	10x1		9	Dry	1	70	25	0.15	120	0.180	11	3	14	0.20	10	Hand touches the riser	Disassembling is finished.
Tee Valve Disconnection		4		9	Dry	1	70	25	0.08	120	0.096	11	3	14	0.13	10	Tee touches the pipe.	Connection is finished.
Tee connection	8.0	4		9	Dry	1	70	25	0.03	120	0.036	11	3	14	0.04	10	Hand touches the tee valve.	Dis-assembly is finished.
Tee Valve Opening	8.0	4		9	Dry	1	70	25	0.16	120	0.192	11	3	14	0.21	10	Hand touches the valve.	Last turn is finished.
Tee Valve Closing	8.0	4		9	Dry	1	70	25	0.16	120	0.192	11	3	14	0.21	10	Hand touches the valve.	Last turn is finished.
Pick up a Pipe	29.8	4x4		9	Dry	2	70	25	0.01	120	0.012	16	3	19	0.02	10	Both men touch pipe.	Pipe is in hands entirely.
Carry the pipe	29.8	4x4	60	9	Dry	2	70	25	0.21	120	0.264	10	3	13	0.28	10	Both men start moving.	Stop near the previous pipe.
Connection	29.8	4x4		9	Dry	2	70	25	0.01	120	0.012	15	3	18	0.02	10	Pipe touches the pipe.	Entirely Male and females are connected.
Lay down a pipe	29.8	4x4		9	Dry	2	70	25	0.01	120	0.012	10	3	13	0.04	10	End of connection.	Hands release the pipe.
Disconnection	29.8	4x4		9	Dry	2	70	25	0.02	120	0.024	15	3	18	0.03	10	Hand touches pipe.	Pipe ends are separated.
Straight line	13.8	4x4		9	Dry	1	70	25	0.07	120	0.084	15	3	18	0.10	10	Touches the pipe.	Connection is finished.
valve connection	17.0	5x5		9	Dry	1	70	25	0.07	120	0.084	15	3	18	0.10	10	Touches the pipe.	Connection is finished.
	20.7	6x6		9	Dry	1	70	25	0.08	120	0.096	15	3	18	0.12	10	Touches the pipe.	Connection is finished.
	40.4	8x8		9	Dry	1	70	25	0.15	120	0.180	40	3	43	0.25	10	Touches the pipe.	Connection is finished.
Straight line	13.8	4x4		9	Dry	1	70	25	0.04	120	0.048	18	3	21	0.05	10	Hands touche the valve	Dis-assembly is finished.
valve disconnection	19.0	5x5		9	Dry	1	70	25	0.05	120	0.060	18	3	21	0.10	10	Hands touch the valve.	Dis-assembly is finished.
	20.7	6x6		9	Dry	1	70	25	0.05	120	0.060	40	3	43	0.07	10	Hands touch the valve.	Dis-assembly is finished.
	40.4	8x8		9	Dry	1	70	25	0.14	120	0.168	40	3	43	0.24	10	Hands touch the valve.	Dis-assembly is finished.
Control tee valve connection	26.8	4x4x4		9	Dry	1	70	25	0.07	120	0.084	40	3	44	0.15	10	Valve touches the pipe.	Connection is finished.
	40.1	5x5x5		9	Dry	1	70	25	0.10	120	0.120	40	3	45	0.21	10	Valve touches the pipe.	Connection is finished.
	43.6	6x6x6		9	Dry	1	70	25	0.18	120	0.216	40	3	43	0.31	10	Valve touches the pipe.	Connection is finished.
	85.0	8x8x8		9	Dry	1	70	25	0.25	120	0.300	40	3	43	0.43	10	Valve touches the pipe.	Connection is finished.
Control Tee Valve disconnection	26.8	4x4x4		9	Dry	1	70	25	0.08	120	0.096	18	3	21	0.14	10	Hand touches the valve.	Dis-assembly is finished.
	40.1	5x5x5		9	Dry	1	70	25	0.15	120	0.300	30	3	33	0.39	10	Hand touches the valve.	Dis-assembly is finished.
	43.6	6x6x6		9	Dry	1	70	25	0.20	110	0.220	35	3	38	0.29	10	Hand touches the valve.	Dis-assembly is finished.
	85.0	8x8x8		9	Dry	1	70	25	0.21	120	0.252	40	3	43	0.35	10	Hand touches the valve.	Dis-assembly is finished.

These times have been recorded in validation conditions in Olivier Chemical Co., Lethbridge, Alberta.



S. T. V. FOR HAND-MOVE SPRINKLER SYSTEMS

Element	Equipment Specification		Work Conditions						Time Study Data					Element Break Points	
	Weight (lb)	Size	Avg Wind Velocity (mph)	Moisture	Temp °F	Grop	Avg crop height (in)	Avg NT (in)	Rest Allowance %	Wind Allowance %	Total Allowance %	No. of observations	Time	Start	Finish
Carrying pipe	29.8	40" x 4"	60	Wet	76	Sugar Beet	18	0.3758	15	6	21	36	0.52	Start walking after pick up.	Stopping at new pipe.
	29.8	40" x 4"	60	Wet	80	Sugar beet	18	0.4145	15	6	21	36	0.57	Start walking after pick up.	Stopping at new pipe.
	29.8	40" x 4"	60	Wet	72	Sugar Beet	16	0.3588	15	8	10	25	0.45	Start walking after pick up.	Stopping at new pipe.
	29.8	40" x 4"	60	Wet	76	Sugar Beet	20	0.3879	15	4	35	46	0.57	Start walking after pick up.	Stopping at new pipe.
	29.8	40" x 4"	60	Wet	66	Sugar Beet	20	0.4711	15	8	10	25	0.54	Start walking after pick up.	Stopping at new pipe.
	29.8	40" x 4"	60	Saturated	70	Sugar Beet	21	0.4821	15	8	10	25	0.60	Start walking after pick up.	Stopping at new pipe.
	29.8	40" x 4"	60	Saturated	68	Sugar Beet	19	0.3811	15	7	15	30	0.50	Start walking after pick up.	Stopping at new pipe.
	29.8	40" x 4"	60	Wet	68	Sugar Beet	12	0.4836	15	7	15	30	0.55	Start walking after pick up.	Stopping at new pipe.
	29.8	40" x 4"	60	Wet	68	Sugar Beet	12	0.4674	15	8	10	25	0.59	Start walking after pick up.	Stopping at new pipe.
	29.8	40" x 4"	60	Wet	62	Sugar Beet	19	0.4409	15	7	15	30	0.59	Start walking after pick up.	Stopping at new pipe.
	29.8	40" x 4"	60	Saturated	65	Sugar Beet	20	0.4606	15	10	2	25	0.58	Start walking after pick up.	Stopping at new pipe.
	29.8	40" x 4"	60	Saturated	68	Flax	18	0.3999	15	8	10	25	0.50	Start walking after pick up.	Stopping at new pipe.
	29.8	40" x 4"	60	Saturated	68	Flax	15	0.3749	15	7	15	46	0.55	Start walking after pick up.	Stopping at new pipe.
	29.8	40" x 4"	60	Wet	69	Beam	5	0.5294	15	5	31	46	0.77	Start walking after pick up.	Stopping at new pipe.
	29.8	40" x 4"	60	Wet	71	Potato	6	0.3989	15	5	31	46	0.58	Start walking after pick up.	Stopping at new pipe.
Connection of lateral pipe	29.8	40" x 4"	60	Wet	80	Potato	7	0.4088	15	5	31	46	0.59	Start walking after pick up.	Stopping at new pipe.
	29.8	40" x 4"	60	Wet	80	Potato	8	0.4149	15	5	31	46	0.61	Start walking after pick up.	Stopping at new pipe.
	29.8	40" x 4"	60	Dry	80	Potato		0.2761	15	5	31	46	0.44	Start walking after pick up.	Stopping at new pipe.
	29.8	40" x 4"	60	Dry	70	Beam	8	0.1386	16	11	2	18	0.16	Pipe touches end of other.	Pipe is laid down.
	29.8	40" x 4"	60	Dry	60	Flax	16	0.1462	16	12		16	0.16	Pipe touches end of other.	Pipe is laid down.
	29.8	40" x 4"	60	Dry	81	Flax	16	0.1537	16	5	31	47	0.23	Pipe touches end of other.	Pipe is laid down.
	29.8	40" x 4"	60	Wet	48	Flax	22	0.1610	16	24		16	0.19	Pipe touches end of other.	Pipe is laid down.
	29.8	40" x 4"	60	Wet	56	Flax	16	0.1652	16	15		16	0.19	Pipe touches end of other.	Pipe is laid down.
	29.8	40" x 4"	60	Dry	70	Flax	16	0.1673	16	10	3	19	0.20	Pipe touches end of other.	Pipe is laid down.
	29.8	40" x 4"	60	Dry	63	Potato	7	0.1459	16	11	2	18	0.17	Pipe touches end of other.	Pipe is laid down.
	29.8	40" x 4"	60	Dry	45	Potato	6	0.1537	16	18		16	0.18	Pipe touches end of other.	Pipe is laid down.
	29.8	40" x 4"	60	Dry	79	Potato	7	0.1668	16	7	15	31	0.22	Pipe touches end of other.	Pipe is laid down.
	29.8	40" x 4"	60	Dry	73	Potato	12.5	0.1766	16	9	3	19	0.21	Pipe touches end of other.	Pipe is laid down.
	29.8	40" x 4"	60	Dry	68	Potato	6.5	0.1790	16	12		16	0.21	Pipe touches end of other.	Pipe is laid down.
	29.8	40" x 4"	60	Dry	71	Potato	6.5	0.1915	16	11	2	18	0.22	Pipe touches end of other.	Pipe is laid down.
Lay down	29.8	40" x 4"	60	Dry	75	Sugar Beet	16	0.1390	16	6	21	37	0.18	Pipe touches end of other.	Pipe is laid down.
	29.8	40" x 4"	60	Dry	65	Sugar Beet	19	0.1453	16	12		16	0.17	Pipe touches end of other.	Pipe is laid down.
	29.8	40" x 4"	60	Dry	79	Sugar Beet	20	0.1471	16	3	64	80	0.27	Pipe touches end of other.	Pipe is laid down.
	29.8	40" x 4"	60	Dry	71	Sugar Beet	20	0.1494	16	10	3	19	0.18	Pipe touches end of other.	Pipe is laid down.
	29.8	40" x 4"	60	Dry	70	Sugar Beet	12	0.1513	16	11	2	18	0.19	Pipe touches end of other.	Pipe is laid down.
	29.8	40" x 4"	60	Dry	75	Sugar Beet	20	0.1514	16	8	10	26	0.19	Pipe touches end of other.	Pipe is laid down.
	29.8	40" x 4"	60	Dry	60	Sugar Beet	20	0.1589	16	17		16	0.17	Pipe touches end of other.	Pipe is laid down.
	29.8	40" x 4"	60	Dry	71	Sugar Beet	16	0.1594	16	8	10	26	0.20	Pipe touches end of other.	Pipe is laid down.
	29.8	40" x 4"	60	Dry	45	Sugar Beet	20	0.1596	16	25		16	0.18	Pipe touches end of other.	Pipe is laid down.
	29.8	40" x 4"	60	Dry	73	Sugar Beet	12	0.1613	16	10	3	19	0.19	Pipe touches end of other.	Pipe is laid down.
	29.8	40" x 4"	60	Dry	71	Sugar Beet	18	0.1618	16	11	2	18	0.19	Pipe touches end of other.	Pipe is laid down.
	29.8	40" x 4"	60	Dry	70	Sugar Beet		0.046	16	10	3	19	0.054	Pipe touches end of other.	Pipe is laid down.
	Average												0.19		
	29.8	40" x 4"	10	Dry	70	Sugar Beet	15	0.041		10	3	19	0.05	Pipe touches end of other.	Pipe is laid down.



S.T.V. FOR HAND MOVE SPRINKLER SYSTEM

Equipment Specification		Work Conditions						Time Study Data.						Element Break Points			
Element	Weight (lbs)	Size (in)	Avg Wind mph	Soil Moisture	No. of operators	Temp °F	R.H. %	Crop	Avg NT (min)	Rest Allowance %	Atmospheric Allowance %	Total Allowance %	S.T.V. (min)	Windchill Figure	Start	Finish	
Pressure Regulating			10	Dry	1	70	23	Flax	7	0.8441	11	3	14	0.9626	10	Touches gas regulator.	Release regulator.
Stopping engine			15	Dry	1	63	31	Potato		0.2048	11		11	0.2273	15	Touch switch.	Release the switch.
Start Engine				Dry	1	55	70	Potato		0.3096	11		11	0.3400	12	Touch switch.	Release the switch.
Checking oil of engine			10	Dry	1	65	39	Sugar Beets		0.2935	11		11	0.3300	14	Touching the gauge.	Releasing gauge.
Adding Oil			5	Dry	1	70	20	Sugar Beets		0.2809	11		11	0.3100	14	pick up oil can.	Release after finished.
Priming		6"	7	Wet	1	65	73	Flax		0.6166	16		16	0.7100	28	Touching the arm.	Releasing the arm.
Pick up pipe	29.8	40"x4"	15	Wet	1	39	67	Flax	15	0.6402	16		16	0.7100	22	Hands touch the pipe.	Pipe completely in hands.
	29.8	40"x4"	20	Wet	1	48	67	Flax	17	0.2000	16		16	0.2200	17	Hands touch the pipe.	Pipe completely in hands.
	29.8	40"x4"	10	Wet	1	50	52	Flax	15	0.6500	16	31	47	0.9500	5	Hands touch the pipe.	Pipe completely in hands.
	29.8	40"x4"	10	Wet	1	83	21	S.Bts	14	0.1650	16	2	18	0.1900	11	Hands touch the pipe.	Pipe completely in hands.
	29.8	40"x4"	16	Wet	1	70	16	S.Bts	10	0.0690	16		16	0.0700	22	Hands touch the pipe.	Pipe completely in hands.
	29.8	40"x4"	17	Wet	1	50	30	S.Bts		0.5900	16		16	0.6800	17	Hands touch the pipe.	Pipe completely in hands.
	29.8	40"x4"	21	Wet	1	63	24	S.Bts		0.2101	16	2	18	0.2400	11	Hands touch the pipe.	Pipe completely in hands.
	29.8	40"x4"	22	Wet	1	72	50	S.Bts		0.6100	16	3	19	0.7300	10	Hands touch the pipe.	Pipe completely in hands.
	29.8	40"x4"	20	Wet	1	81	39	S.Bts		0.4300	16		16	0.5000	51	Hands touch the pipe.	Pipe completely in hands.
	29.8	40"x4"	3	Wet	1	63	73	S.Bts		0.4800	16		16	0.5100	17	Hands touch the pipe.	Pipe completely in hands.
	29.8	40"x4"	3	Wet	1	60	30	S.Bts		0.4100	16		16	0.4700	17	Hands touch the pipe.	Pipe completely in hands.
	29.8	40"x4"	16	Wet	1	48	40	Potato		0.2300	16		16	0.2700	22	Hands touch the pipe.	Pipe completely in hands.
	29.8	40"x4"	10	Wet	1	39	81	Potato		0.1900	16		16	0.2500	28	Hands touch the pipe.	Pipe completely in hands.
	29.8	40"x4"	7	Wet	1	69	61	Potato		0.6600	16	2	18	0.7200	11	Hands touch the pipe.	Pipe completely in hands.
	29.8	40"x4"	3	Wet	1	73	50	Potato		0.6100	16	3	19	0.7700	10	Hands touch the pipe.	Pipe completely in hands.
	29.8	40"x4"	18	Wet	1	75	38	Potato		0.0710	16	10	26	0.0890	8	Hands touch the pipe.	Pipe completely in hands.
	29.8	40"x4"	10	Wet	1	80	51	Beans		0.4300	16	31	47	0.6300	5	Hands touch the pipe.	Pipe completely in hands.
	29.8	40"x4"	10	Wet	1	80	11	Beans		0.5800	16	31	47	0.8500	5	Hands touch the pipe.	Pipe completely in hands.
	29.8	40"x4"	10	Wet	1	48	17	Beans		0.3100	16		16	0.3600	22	Hands touch the pipe.	Pipe completely in hands.
	29.8	40"x4"	11	Wet	1	66	16	Beans		0.3000	16		16	0.3400	17	Hands touch the pipe.	Pipe completely in hands.
	29.8	40"x4"	10	Wet	1	72	31	Beans		0.4900	16	2	18	0.5700	11	Hands touch the pipe.	Pipe completely in hands.
Validation Average	29.8	40"x4"	8	Dry	1	78	25	-	-	-	-	-	-	0.0400	-	-	-
	29.8	40"x4"	-	-	-	-	-	-	-	-	-	-	-	0.4800	-	-	-

Note: This weight is weight of pipe only.



S.T.V. FOR OPERATION IN SPRINKLER  
HAND MOVE SYSTEM.

Elements	Work Conditions							Time Study Data							Elements Break Points		
	Distance (ft)	Avg Wind Velocity (mph)	Soil Surface Moisture	No. of operators	Temp ° F	R.H. %	Crops	Avg height of crops	Avg NT (min)	Rest Allow ance %	Wind Chill Numbers	Atmospheric Allowance %	Total Allowance %	S.T.V. (min)	No. of ob- servations	Start	Finish
Walking ( Unloaded)	60'	1	Wet	1	60	15	Bean	8	0.5547	11	10	3	14	0.61	88	Pipe out of hands completely.	Touch the new pipe.
	60'	8	Saturated	1	66	12	Flax	15	0.4209	11	14		11	0.46	40	Pipe out of hands completely.	Touch the new pipe.
	60'	6	Saturated	1	60	10	Flax	16	0.4574	11	17		11	0.50	72	Pipe out of hands completely.	Touch the new pipe.
	60'	10	Saturated	1	60	13	Flax	21	0.4605	11	15		42	0.48	64	Pipe out of hands completely.	Touch the new pipe.
	60'	6	Saturated	1	76	25	Flax	7	0.4648	11	15		42	0.48	64	Pipe out of hands completely.	Touch the new pipe.
	60'	5	Saturated	1	60	30	Potato	7	0.4632	11	13		11	0.50	80	Pipe out of hands completely.	Touch the new pipe.
	60'	6	Wet	1	58	40	Potato	9	0.4607	11	17		11	0.50	56	Pipe out of hands completely.	Touch the new pipe.
	60'	4	Very wet	1	68	20	Potato	13	0.5321	11	13		11	0.50	56	Pipe out of hands completely.	Touch the new pipe.
	60'	6	Very wet	1	48	40	Potato	15	0.5971	11	19		11	0.60	72	Pipe out of hands completely.	Touch the new pipe.
	60'	10	Very wet	1	51	70	Potato	7	0.6230	11	18		11	0.61	32	Pipe out of hands completely.	Touch the new pipe.
	60'	10	Very wet	1	60	70	Potato	20	0.6318	11	14		11	0.63	72	Pipe out of hands completely.	Touch the new pipe.
	60'	5	Very wet	1	55	36	Sugar Beet	11	0.4512	11	13		11	0.50	32	Pipe out of hands completely.	Touch the new pipe.
	60'	16	Very wet	1	59	11	Sugar Beet	19	0.4791	11	19		11	0.51	32	Pipe out of hands completely.	Touch the new pipe.
	60'	11	Very wet	1	68	12	Sugar Beet	20	0.4872	11	12		11	0.53	72	Pipe out of hands completely.	Touch the new pipe.
	60'	8	Very wet	1	58	26	Sugar Beet	17	0.4872	11	13		11	0.53	48	Pipe out of hands completely.	Touch the new pipe.
	60'	6	Very wet	1	54	30	Sugar Beet	20	0.5078	11	13		11	0.53	56	Pipe out of hands completely.	Touch the new pipe.
	60'	16	Very wet	1	56	28	Sugar Beet	12	0.5081	11	17		11	0.55	96	Pipe out of hands completely.	Touch the new pipe.
Average for 60' Average for 100'	60'	17	Very wet	1	60	15	Sugar Beet	20	0.5094	11	17		11	0.55	24	Pipe out of hands completely.	Touch the new pipe.
	60'	17	Very wet	1	62	80	Sugar Beet	20	0.5105	11	14		11	0.55	88	Pipe out of hands completely.	Touch the new pipe.
	60'	10	Very wet	1	71	16	Sugar Beet	19	0.5135	11	12		11	0.58	48	Pipe out of hands completely.	Touch the new pipe.
	60'	16	Very wet	1	76	13	Sugar Beet	21	0.5208	11	12		11	0.52	64	Pipe out of hands completely.	Touch the new pipe.
	60'	11	Very wet	1	73	20	Sugar Beet	20	0.5321	11	12		11	0.58	48	Pipe out of hands completely.	Touch the new pipe.
	60'	3	Very wet	1	51	18	Sugar Beet	20	0.5453	11	20		11	0.59	56	Pipe out of hands completely.	Touch the new pipe.
	100'	10	Very wet	1	70	25	Sugar Beet	15	0.8206	11	10	3	14	0.94		Pipe out of hands completely.	Touch the new pipe.
															0.54/60'		
															0.84/100'		



## S.T.V. FOR WHEEL-MOVE SPRINKLER SYSTEMS.

ELEMENT	Equipment Specification			Work Conditions					Time Study Data						Element Break Points.			
	Weight (lbs)	Size	Distance (ft)	Avg. Wind <sup>1</sup>	Soil Surface Moisture	No. of operators	Avg Temp.	Crop	Crop Height	Avg. NT	Rest Allow- ance %	Windkill Factor	Allow- ance %	Total Allowances	S.T.V. (min)	No. of ob- servations	START	FINISH
Turn Off the Engine				10	Dry	1	70	Flax		0.3979	11	10	3	14	0.45	17	Touch the switch	Motor Stopped.
Close elbow valve		4"x4"		8	Dry	1	65	Flax		0.5172	14	12		14	0.59	10	Elbow valve touches pipe.	Completely assembled.
Disconnection of first pipe	15	2"x4"		13	Dry	1	71	Flax	10	0.4071	15	11	2	17	0.47	25	Hand touches pipe.	Completely disconnected
Rushing connector ring				10	Dry	1	68	Flax	13	0.4280	15	10	3	18	0.49	32 30 30		
Carry the supportor	6		60	16	Dry	1	78	Flax	16	0.4351	15	7	15	30	0.56	20	Rough the supportor.	Lay it down.
Valve connection		6"		16	Dry	1	71	Flax	18	0.2840	15	11	2	17	0.33	20 35	Touch the valve.	Connection is completed
Lay down first pipe	15	20'		16	Dry	1	72	Flax	18	0.4017	15	11	2	17	0.47	30 35	Touch the pipe.	Lay it down.
Walk 1/4 mile			1320	15	Wet	1	88	Flax	18	5.0000	16	64	3	80	9.00	30	Short Walking.	Stop near the mover.
Take cover off	4			11	Wet	1	48	Flax	20	0.1744	14	11		14	0.20	30 40	Touch the cover.	Put it aside.
Start the move engine				10	Wet	1	50	Flax	18	0.3272	11	18		11	0.36	30 30	Touch the switch.	Engine mover starts.
System moving	1000	1/4	60	10	Wet	1	60	Flax	18	3.1482		15			3.15	30 30	Start moving.	Stop moving.
Replace cap.	4			13	Wet	1	71	Flax	16	0.1227	11	11	2	13	0.14	30	Touch the cap.	Replaced.
Pull first pipe back	13	20'	10	17	Dry	1	68	Flax	21	0.3237	11	11	2	13	0.36	35 35	Touch the pipe.	Replace it.
Pick up supportor	6			15	Dry	1	68	Flax	18	0.4740	14	14		14	0.53	30	Touch the support.	Complete under hand control.
Tighten pipe				10	Dry	1	70	Flax	18	0.4343	14	9	3	17	0.53	30	Touch ring.	Tighten it.
Open valve	3.6	6"		13	Wet	1	68	Flax	18	0.3383	15	11	2	17	0.40	30	Touch the valve.	Opened completely.
Start motor.				10	Dry	1	70	Flax	20	0.3897	15	10	3	18	0.45	30	Touch switch.	Motor started.
Priming.	5.5	6"		11	Wet	1	75	Flax	18	0.1276	15	8	10	25	0.16	30	Start priming.	Finish priming.
Regulate motor.				10	Wet	1	65	Flax	16	0.3189	15	12		15	0.37	35	Touch switch.	Take off hand.
Checking valve and motor				16		1	70	Flax		0.4976	13	11	2	17	0.58	33	Start checking.	Finish checking.



S.T.V. FOR GRAVITY SYSTEM.

Element	Equipment Specification		Work Conditions							Time Study Data							Element Break Points		
	Weight (lbs)	Size (in.)	Distance (ft)	Avg Wind Velocity (mph)	Surface Moisture	No. of operators.	Temp F°	Crop	Avg Height of crop (in.)	Avg NT (min)	Rest Allowance %	Wind chill figure	Atmospheric Allowance %	Total Allowance %	No. of observations	S.T.V. For two men	S.T.V. Man + time (min)	Start	Finish
Pick Up Canvas	8	8x6		3	Wet	2	70	Alfalfa	24	0.4862	15	9	3	18	22	0.561	1.11	Touching Canvas	All canvas is under hand control
Passing Rod through Canvas				3	Wet	2	65	Alfalfa	8	0.5362	15	9	3	18	20	0.63	1.26	Rod Touches canvas.	All rod passed through the canvas.
Carrying canvas	8	8x6	90	7	Wet	1	71	Alfalfa	8	0.7650	15	9	3	18	20	0.89	1.78	Moving with canvas.	Stop at new position.
Place Canvas in ditch.	8	8x6		10	Dry	2	81	Alfalfa	16	0.6625	15	5	31	46	20	0.97	1.94	End of previous element	Completely placed in ditch
Place mud to keep canvas					Wet	2	73	Alfalfa	16	2.1700	11	6	21	36	26	2.9	5.8	Start Shoveling dirt and mud.	Finish shoveling.

Note: Size of pipe is 40 ft long by 4 in. in diameter and weighs 29.8 lbs.



S.T.V. FOR MOVING LATERAL PIPES--ONE OPERATOR

Size of Pipe		10 ft				20 ft				30 ft				40 ft				50 ft				60 ft			
No. of Pipes Carried Each Time	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
Pick up	0.35	0.39	0.43	0.48	0.39	0.48	0.57	0.65	0.43	0.57	0.70	0.83	0.48	0.65	0.83	1.04	0.32	0.74	1.00	1.20	0.57	0.83	1.03	1.39	
Carry	0.56	0.76	0.85	0.93	0.76	1.04	1.22	1.59	0.85	1.34	1.60	1.85	0.93	1.59	1.85	2.19	1.01	1.57	2.18	2.79	1.10	1.74	2.44	3.20	
Connect	0.14	0.17	0.17	0.19	0.17	0.19	0.22	0.26	0.17	0.22	0.26	0.33	0.10	0.26	0.34	0.41	0.21	0.31	0.40	0.48	0.22	0.34	0.45	0.55	
Walk back	0.55	0.66	0.77	0.90	0.62	0.86	1.13	1.43	0.69	1.08	1.54	2.01	0.77	1.34	1.96	2.61	0.87	1.60	2.40	3.22	0.97	1.88	2.85	3.85	

Size of Pipe		70 ft				80 ft				90 ft				100 ft				110 ft				120 ft			
No. of Pipes Carried Each Time	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
Pick up	0.61	0.95	1.26	1.56	0.65	1.04	1.39	1.73	0.70	1.13	1.52	1.90	0.74	1.20	1.65	2.08	0.78	1.30	1.38	2.25	0.83	1.39	1.90	2.42	
Carry	1.18	1.91	2.68	3.46	1.26	2.08	3.01	3.79	1.35	2.24	3.18	3.46	1.43	2.40	3.44	4.46	1.52	2.59	3.69	4.80	1.60	2.82	3.94	3.19	
Connect	0.24	0.38	0.50	0.53	0.26	0.41	0.55	0.60	0.27	0.45	0.60	0.75	0.29	0.48	0.65	0.82	0.31	0.52	0.70	0.89	0.34	0.33	0.76	0.96	
Walk Back	1.07	2.16	3.30	4.60	1.18	2.44	3.76	5.08	1.28	2.72	4.21	5.74	1.39	3.91	4.67	6.33	1.51	3.30	5.13	6.96	1.63	3.59	5.62	7.52	



## APPENDIX B

### FORMULAE

The following empirical formulae were written and used for calculation of S.T.V. in the various methods.

#### 1. Connection after each pipe is moved.

##### One Pipe At A Time

$$T_{car} = \frac{1320}{L} \left[ \left( \frac{0.68^*}{100} \right) \left( \frac{9L + 1000}{1000} \right) 60 \right]$$

$$\therefore = \frac{1320}{L} \left[ 0.408^* \left( \frac{9L + 1000}{1000} \right) \right]$$

$$\therefore = \frac{54}{L} \left( \frac{9L + 1000}{1000} \right)$$

$$T_{car} = \frac{54}{L} (\alpha_1) \quad (1)$$

$$T_w = \left[ \frac{1320}{L} (\sqrt{L^2 + 60^2}) + 1320 \right] \left( \frac{0.84^*}{100} \right)$$

$$T_w = 0.0084 \left[ (\sqrt{L^2 + 60^2}) + 1320 \right] \quad (2)$$

$$T_p = \left( \frac{1320}{L} \right) \left[ (0.35)^* \left( \frac{9L + 1000}{1000} \right) \right]$$

$$T_p = \frac{462}{L} (\alpha_1) \quad (3)$$

$$T_c = \left( \frac{1320}{L} \right) \left[ (0.14)^* \left( \frac{9L + 1000}{1000} \right) \right]$$

$$T_c = \frac{185}{L} (\alpha_1) \quad (4)$$

$$T_t = T_{car} + T_w + T_p + T_c \quad (5)$$

\*As it was mentioned in Part II, for each increase in length of pipe the S.T.V. will be added 0.09 per 10' then,

$$= 1 + 0.09 \times \frac{L}{10} = \frac{9L + 1000}{1000} \text{ for one pipe at a time.}$$

$$= 1 + 0.09 \times 2 \times \frac{L}{10} = \frac{18L + 1000}{1000} \text{ for two pipes at a time.}$$

$$= 1 + 0.09 \times 3 \times \frac{L}{10} = \frac{27L + 1000}{1000} \text{ for three pipes at a time.}$$

$$= 1 + 0.09 \times 4 \times \frac{L}{10} = \frac{36L + 1000}{1000} \text{ for four pipes at a time.}$$



Two Pipes At A Time

$$T_{car} = \left[ \left( \frac{0.68}{100} \right)^* (2L) + \left( \frac{18L + 1000}{1000} \right) (.558) \right] \frac{1320}{2L}$$

$$T_{car} = \left[ 0.0186L + (\alpha_2)(.558) \right] \frac{660}{L} \quad (6)$$

$$T_w = \frac{1320}{2L} \left[ \left( \sqrt{L^2 + (4L)^2} \right) \left( \frac{0.84}{100} \right)^* \right] + (1320) \left( \frac{0.84}{100} \right)^*$$

$$T_w = 11.1 + \left( \sqrt{(60)^2 + (2L)^2} \right) \left( \frac{5.54}{L} \right) \quad (7)$$

$$T_p = \frac{1320}{2L} \left[ \left( 0.35 \right)^* \left( \frac{9L + 1000}{1000} \right) (2) + \left( 0.35 \right)^* \left( \frac{18L + 1000}{1000} \right) \right]$$

$$T_p = \frac{231}{L} (2\alpha_1 + \alpha_2) \quad (8)$$

$$T_{Ld} = \frac{26.4}{L} (\alpha_1 + \alpha_2) \quad (9)$$

$$T_c = \frac{185}{L} (\alpha_1) \quad (10)$$

$$T_t = T_{car} + T_w + T_{Ld} + T_c + T_p \quad (11)$$

Three Pipes At A Time

$$T_w = \frac{3}{2}L \left( \frac{0.84}{100} \right)^* + \left( \frac{0.84}{100} \right)^* \left( \frac{1320}{3L} \right) \left( \sqrt{(31)^2 + (60)^2} \right)$$

$$T_w = \left( \frac{0.84}{100} \right)^* \left[ \left( \frac{3}{2}L \right) + \left( \frac{440}{L} \right) \sqrt{(3L)^2 + (60)^2} + 1320 \right] \quad (12)$$

$$T_{car} = \left( \frac{1320}{3L} \right) \cdot \left( \frac{0.68}{100} \right)^* \left[ \left( \frac{9L + 1000}{1000} \right) \cdot (2L) + \left( \frac{18L + 1000}{1000} \right) (2L) + 60 \left( \frac{27L + 1000}{1000} \right) \right]$$

$$T_{car} = \left( \frac{2.99}{L} \right) \left[ 2L \left( \frac{9L + 1000}{1000} \right) + 2L \left( \frac{18L + 1000}{1000} \right) + 60 \left( \frac{27L + 1000}{1000} \right) \right]$$

$$T_{car} = \frac{2.99}{L} (2L\alpha_1 + 2L\alpha_2 + 60\alpha_3) \quad (13)$$



$$T_p = \left(\frac{154}{L}\right) \left[ 2\left(\frac{9L + 1000}{1000}\right) + 2\left(\frac{18L + 1000}{1000}\right) + \left(\frac{27L + 1000}{1000}\right) \right]$$

$$T_p = \frac{154}{L} (2d_1 + 2d_2 + d_3) \quad (14)$$

$$T_c = \frac{185}{L} (d_1) \quad (15)$$

$$T_t = T_w + T_{car} + T_p + T_{Ld} + T_c \quad (16)$$

#### Four Pipes At A Time

$$T_w = 3.5L \left(\frac{0.84}{100}\right)^* + \frac{1320}{4L} \left(\frac{0.84}{100}\right)^* \sqrt{(60)^2 + (4L)^2} + 1320 \left(\frac{.84}{100}\right)^*$$

$$T_w = 0.0084 \left( 3.5L + \frac{330}{L} \sqrt{(4L)^2 + (60)^2} + 1320 \right) \quad (17)$$

$$T_{car} = \frac{2.24}{L} (2Ld_1 + 2Ld_2 + 2Ld_3 + 60Ld_4) \quad (18)$$

$$T_p = \frac{115.5}{L} (2d_1 + 2d_2 + 2d_3 + d_4) \quad (19)$$

$$T_{Ld} = \frac{1320}{4L} (0.04)^* (d_1 + 2d_2 + 2d_3 + d_4)$$

$$T_{Ld} = \frac{13.2}{L} (d_1 + 2d_2 + 2d_3 + d_4) \quad (20)$$

$$T_c = \frac{185}{L} (d_1) \quad (21)$$

$$T_t = T_{car} + T_w + T_p + T_c + T_{Ld} \quad (22)$$

## 2. Connection After All Pipes Are Moved To New Position

#### Two Pipes At A Time

$$T_w = \left( L^2 + 3600 \right) \frac{5.544}{L} \quad (23)$$



$$T_{\text{car}} = 4.48^* \left[ 2L + 60 \frac{18L + 1000}{1000} \right]$$

$$T_{\text{car}} = 4.48^* \left[ 2L + 60(d_2) \right] \quad (24)$$

$$T_p = \frac{231}{L} (2d_1 + d_2) \quad (25)$$

$$T_{\text{Ld}} = \frac{26.4}{L} (2d_1 + d_2) \quad (26)$$

$$T_c = \frac{185}{L} (d_1) \quad (27)$$

$$T_t = T_w + T_{\text{car}} + T_p + T_c + T_{\text{Ld}} \quad (28)$$

#### Three Pipes At A Time

$$T_w = \frac{3.73}{L} \left( \sqrt{(60^2 + (L)^2)} \right) \quad (29)$$

$$T_{\text{car}} = \frac{2.99}{L} (2Ld_1 + 2Ld_2 + 60d_3) \quad (30)$$

$$T_p = \frac{154}{L} (2d_1 + 2d_2 + d_3) \quad (31)$$

$$T_{\text{Ld}} = \frac{17.6}{L} (2d_1 + 2d_2 + d_3) \quad (32)$$

$$T_c = \frac{185}{L} (d_1) \quad (33)$$

#### Four Pipes At A Time

$$T_w = \left( \sqrt{(60)^2 + L^2} \right) \frac{2.77}{L} \quad (34)$$

$$T_{\text{car}} = \frac{2.24}{L} (2Ld_1 + 2Ld_2 + 2Ld_3 + 60d_4) \quad (35)$$

$$T_p = \left( \frac{115.5}{L} \right) (2d_1 + 2d_2 + 2d_3 + d_4) \quad (36)$$



$$T_{Ld} = \frac{13.2}{L} (2\alpha_1 + 2\alpha_2 + 2\alpha_3 + \alpha_4) \quad (37)$$

$$T_c = \frac{185}{L} (\alpha_1) \quad (38)$$

$$T_t = T_w + T_{car} + T_p + T_{Ld} + T_c \quad (39)$$

#### ABBREVIATIONS

S.T.V. = standard time value

$T_w$  = S.T.V. for walking

$T_{car}$  = S.T.V. for carrying of specific size

$T_p$  = S.T.V. for pick-up

$T_{Ld}$  = S.T.V. for lay down of specific size of pipe

$T_c$  = S.T.V. for connection

$T_t$  = total S.T.V.'s for moving 1/4 mile system

$L$  = Length of each piece of pipe in feet.

$\alpha_1 = \frac{9L + 1000}{1000}$  a coefficient found in study.

$\alpha_2 = \frac{18L + 1000}{1000}$  a coefficient found in study.

$\alpha_3 = \frac{27L + 1000}{1000}$  a coefficient found in study.

$\alpha_4 = \frac{36L + 1000}{1000}$  a coefficient found in study.

Note: (1) All S.T.Values are in minutes and are for 1/4 mile system.

(2) A 1/4 mile system was chosen as a unit = 1320 feet.

(3) S.T.V.'s are for specified size that is used in formulae.


\*These figures are taken from Table 18 and represent the time in minutes for performance of related task when the length of the pipe is 10 ft.




APPENDIX C

ALTERNATIVE LATERAL MOVEMENT METHODS

One Pipe Each Time



















Element No.	Element	American Society of Mechanical Engineer's Symbols
1	Pick up a pipe	
2	Carry pipe to new position	
3	Lay it down and connect it	
4	Walk back for second pipe and so on	

Two Pipes Each Time

Element No.	Element	American Society of Mechanical Engineer's Symbols
1	Pick up the first pipe	
2	Carry the pipe to the second pipe	
3	Lay down the first pipe	
1	Pick up both pipes	
2	Carry both pipes to new position for one	
3	Lay down the first pipe	
3	Connect the first pipe	
1	Pick up the second pipe	
2	Carry second pipe to its new position	
3	Connect the second pipe	
4	Walk back to the third pipe and so on	





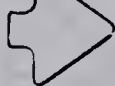















Three Pipes Each Time

Element No.	Element	American Society of Mechanical Engineer's Symbols
1	Pick up first pipe	
2	Carry it to the second pipe	
3	Lay down the first pipe	
1	Pick up first and second pipes	
2	Carry first and second pipes to the third pipe	
3	Lay first and second pipes down	
1	Pick up all pipes	
2	Carry all pipes to new position	
3	Lay all pipes down	
3	Connect the first pipe	
1	Pick up first and second pipes	
2	Carry first and second pipes to next position	
3	Lay first and second pipes down	
3	Connect the second pipe	
1	Pick up the third pipe	
2	Carry third pipe to next position	
3	Connect the third pipe	
4	Walk back	







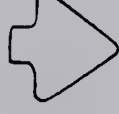


Four Pipes Each Time

Element No.	Element	American Society of Mechanical Engineer's Symbols
1	Pick up first pipe	
2	Carry first pipe to second pipe	
3	Lay first pipe down	
1	Pick up first and second pipe	
2	Carry first and second pipes to third pipe	
3	Lay first and second pipes down	
1	Pick up first, second and third pipes	
2	Carry first, second and third pipes to fourth pipe	
3	Lay first, second and third pipes down	
1	Pick up first, second, third and fourth pipes	
2	Carry all pipes to new position	
3	Lay all pipes down	
3	Connect the first pipe	
1	Pick up second, third and fourth pipes	
2	Carry second, third and fourth pipes to next position	
3	Lay second, third and fourth pipes down	
3	Connect the second pipe	
1	Pick up third and fourth pipes	

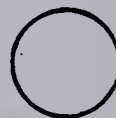


Four Pipes Each Time

Element No.	Element	American Society of Mechanical Engineer's Symbols
2	Carry third and fourth pipes to next position	
3	Lay third and fourth pipes down	
3	Connect the third pipe	
1	Pick up fourth pipe	
2	Carry fourth pipe to next position	
3	Connect fourth pipe	
4	Walk back	

American Society of Mechanical Engineer's Symbols Meaning:

Operation



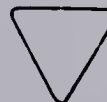
Transportation



Delay



Inspection





## 119 -





S.T.V. for One Operator with Present Method, For Moving a 1/4 Mile Lateral Pipe.

Size of Pipe	One Pipe At A Time						Two Pipes At A Time						Three Pipes At A Time						Four Pipes At A Time					
	T <sub>w</sub>	T <sub>car</sub>	T <sub>p</sub>	T <sub>c</sub>	T <sub>t</sub>		T <sub>w</sub>	T <sub>car</sub>	T <sub>p</sub>	T <sub>Ld</sub>	T <sub>c</sub>	T <sub>t</sub>	T <sub>w</sub>	T <sub>car</sub>	T <sub>p</sub>	T <sub>Ld</sub>	T <sub>c</sub>	T <sub>t</sub>	T <sub>w</sub>	T <sub>car</sub>	T <sub>p</sub>	T <sub>Ld</sub>	T <sub>c</sub>	T <sub>t</sub>
10	78.60	58.86	50.36	20.16	207.93		45.11	40.67	77.61	5.99	20.65	190.03	35.97	36.48	88.80	8.27	20.65	190.17	12.26	34.04	97.25	9.68	20.65	173.88
20	46.00	31.86	27.26	10.99	116.11		29.99	27.27	42.96	3.47	10.15	113.80	27.01	28.96	50.97	4.79	10.15	121.88	12.65	29.40	57.00	5.74	10.15	114.94
30	34.75	23.86	19.45	7.87	85.04		25.64	22.70	31.41	2.47	7.82	90.04	26.61	27.46	36.87	3.46	7.82	102.22	12.18	28.95	42.04	4.25	7.82	96.28
40	30.98	18.36	15.81	6.28	71.43		24.08	80.51	25.61	2.03	6.25	78.49	23.87	27.45	31.31	3.63	6.28	98.04	13.77	31.36	36.48	3.76	6.28	91.65
50	28.77	17.40	13.39	5.35	64.92		22.20	19.64	22.17	1.77	5.36	71.20	23.62	28.08	27.15	2.66	5.36	86.87	14.37	32.47	32.80	3.32	5.36	88.39
60	26.60	13.86	11.86	4.77	57.09		21.24	18.30	19.86	1.59	4.74	65.73	23.51	22.08	24.65	2.41	4.74	77.37	14.98	34.67	30.03	3.10	4.74	87.52
70	25.50	12.55	10.76	4.83	53.04		21.23	17.61	18.21	1.47	4.30	62.81	23.46	30.70	23.47	2.26	4.30	84.19	15.44	37.12	28.29	2.95	4.30	87.10
80	24.94	11.52	9.92	3.91	50.29		21.27	17.13	16.93	1.37	3.97	60.62	23.55	31.45	21.05	2.06	3.97	82.08	16.20	39.34	26.09	2.69	3.77	88.09
90	24.32	10.86	9.98	3.61	48.77		21.18	16.75	15.97	1.28	3.71	58.89	23.64	33.16	20.89	1.99	3.71	83.39	16.86	40.32	25.75	2.79	3.71	89.36
100	23.88	10.26	8.77	3.44	46.35		21.14	16.60	15.24	1.28	3.51	57.87	23.65	34.71	19.65	1.90	3.51	83.42	17.55	43.03	24.48	2.52	3.51	91.09
110	23.76	9.75	8.36	3.38	45.25		20.12	13.93	14.61	1.18	3.34	55.18	23.74	36.96	19.47	1.90	3.34	85.41	18.07	45.98	23.98	2.50	3.34	93.87
120	23.18	9.36	8.00	3.20	43.74		20.10	15.90	14.13	1.16	3.20	54.49	23.77	37.38	17.14	1.77	3.20	85.80	18.70	46.71	23.33	2.44	3.20	94.38



S.T.V. for Moving a 1/4 Mile Lateral Pipe by One Operator--New Method.

No. of lateral pipes to be moved	Two Pipes At A Time						Three Pipes At A Time						Four Pipes At A Time					
	T <sub>w</sub>	T <sub>car</sub>	T <sub>p</sub>	T <sub>LD</sub>	T <sub>c</sub>	T <sub>t</sub>	T <sub>w</sub>	T <sub>car</sub>	T <sub>p</sub>	T <sub>LD</sub>	T <sub>c</sub>	T <sub>t</sub>	T <sub>w</sub>	T <sub>car</sub>	T <sub>p</sub>	T <sub>LD</sub>	T <sub>c</sub>	T <sub>t</sub>
10	33.07	46.67	77.40	8.87	20.65	180.84	22.68	36.48	88.80	10.15	20.65	178.76	16.86	34.64	97.25	11.11	20.65	179.94
20	15.50	27.23	42.76	4.91	10.15	100.03	10.58	28.96	50.97	5.82	10.15	106.48	8.94	29.40	57.00	5.53	10.15	111.01
30	12.33	22.70	31.41	3.59	7.82	77.85	7.97	27.46	36.87	4.19	7.82	84.31	6.16	28.93	42.04	4.80	7.82	89.75
40	9.93	20.51	25.51	2.93	6.28	65.26	6.04	27.45	31.31	3.62	6.28	74.70	4.96	31.36	36.48	4.40	6.28	83.26
50	8.59	19.04	22.17	2.54	5.36	57.70	5.23	28.08	27.15	3.17	5.36	68.99	4.29	39.47	32.88	3.69	5.36	85.69
60	7.63	18.30	19.86	2.27	4.74	52.80	4.75	22.06	24.65	2.86	4.74	59.06	3.86	34.67	30.03	3.44	4.74	76.74
70	7.40	17.60	18.21	2.09	4.30	41.60	4.42	31.45	23.47	2.87	4.30	60.31	3.59	37.13	28.89	3.26	4.30	76.56
80	7.00	17.13	16.93	1.95	3.97	46.97	4.20	27.20	21.05	2.44	3.97	58.86	3.40	39.35	26.09	2.49	3.97	75.77
90	6.49	16.75	15.97	1.81	3.71	44.83	4.00	33.16	20.89	2.34	3.71	64.10	3.25	40.32	25.75	2.91	3.71	75.94
100	6.81	16.60	15.24	1.72	3.51	43.88	3.83	34.77	19.65	2.23	3.51	63.99	3.24	43.03	24.47	2.76	3.51	77.01
110	5.70	15.93	14.61	1.67	3.34	41.95	3.76	36.92	19.47	2.22	3.34	64.97	3.13	45.24	23.98	2.74	3.34	78.47
120	5.62	15.90	14.13	1.61	3.20	41.64	3.75	37.38	19.14	2.06	3.20	72.53	3.08	46.71	23.33	2.67	3.90	78.99



Table S.T.V. For Two Operators with Present Method For Moving a 1/4 Mile Lateral Pipes

Size of Pipes	One Pipe At A Time					Two Pipes At A Time					Three Pipes At A Time					Four Pipes At A Time							
	T <sub>w</sub>	T <sub>car</sub>	T <sub>p</sub>	T <sub>c</sub>	T <sub>t</sub>	T <sub>w</sub>	T <sub>car</sub>	T <sub>p</sub>	T <sub>Ld</sub>	T <sub>c</sub>	T <sub>t</sub>	T <sub>w</sub>	T <sub>car</sub>	T <sub>p</sub>	T <sub>Ld</sub>	T <sub>c</sub>	T <sub>t</sub>	T <sub>w</sub>	T <sub>car</sub>	T <sub>p</sub>	T <sub>Ld</sub>	T <sub>c</sub>	T <sub>t</sub>
10	78.60	28.25	16.68	4.54	277.28	45.11	19.52	25.41	1.78	4.54	193.52	35.97	17.41	29.30	2.72	4.54	180.10	12.26	16.34	38.90	3.19	5.54	115.20
20	48.22	15.29	8.99	2.23	149.02	29.99	13.07	14.18	1.10	9.23	121.14	27.01	13.90	16.82	1.58	2.23	123.80	12.65	14.11	18.81	1.89	2.23	99.38
30	47.75	10.97	6.45	1.72	133.78	23.64	10.89	10.37	0.82	1.72	98.88	96.11	13.42	12.17	1.14	1.72	110.12	13.18	13.89	13.87	1.40	1.72	88.16
40	30.98	8.80	5.22	1.38	92.96	24.00	9.84	8.45	0.67	1.38	88.68	93.97	13.17	10.33	2.99	1.38	99.68	13.77	15.05	12.04	1.24	1.38	86.96
50	28.77	8.35	4.42	1.18	85.44	22.96	9.43	7.32	0.58	1.18	81.54	23.69	13.48	8.96	0.88	1.18	96.21	12.37	15.59	10.82	1.10	1.18	86.12
60	26.66	6.65	3.91	1.04	76.40	21.24	8.78	6.55	0.52	1.04	76.32	23.51	10.59	8.13	0.79	1.04	88.19	14.98	16.81	9.91	1.02	1.04	87.18
70	25.50	6.02	3.58	0.95	72.10	21.23	8.55	6.00	0.46	0.95	74.18	23.46	14.74	7.75	0.75	0.95	95.30	15.44	17.82	9.33	0.97	0.95	89.89
80	24.94	5.53	3.37	0.87	64.22	21.22	8.22	5.60	0.45	0.87	72.72	23.55	13.06	7.09	0.68	0.87	90.50	16.20	18.88	8.61	0.89	0.87	86.40
90	24.39	5.21	3.06	0.82	66.82	21.18	8.04	5.27	0.42	0.82	71.46	23.64	15.07	6.89	0.66	0.82	94.06	16.86	19.35	8.50	0.99	0.82	91.01
100	23.88	4.92	2.89	0.94	64.92	20.14	7.97	5.03	0.41	0.77	68.72	23.65	16.19	6.48	0.63	0.79	96.18	17.56	20.65	8.07	0.82	0.77	95.74
110	23.76	4.68	2.76	0.75	63.90	20.12	7.65	4.82	0.39	0.75	67.46	23.74	17.74	6.43	0.63	0.75	98.46	18.07	22.07	7.91	0.82	0.75	99.24
120	23.18	4.49	2.64	0.70	62.03	20.10	7.63	4.66	0.38	0.70	66.95	23.97	14.58	6.32	0.58	0.70	107.60	18.70	22.42	7.70	0.81	0.70	100.66



S.T.V. for moving a 1/4 Mile Lateral Pipe by Two Operators

Size of Pipes	Two Pipes At A Time						Three Pipes At A Time						Four Pipes At A Time					
	T <sub>w</sub>	T <sub>car</sub>	T <sub>p</sub>	T <sub>Ld</sub>	T <sub>c</sub>	T <sub>t</sub>	T <sub>w</sub>	T <sub>car</sub>	T <sub>p</sub>	T <sub>Ld</sub>	T <sub>c</sub>	T <sub>t</sub>	T <sub>w</sub>	T <sub>car</sub>	T <sub>p</sub>	T <sub>Ld</sub>	T <sub>c</sub>	T <sub>t</sub>
10	33.07	19.59	25.61	2.93	5.54	173.34	22.68	17.57	29.30	3.35	5.54	156.75	16.89	16.34	32.09	3.67	5.54	149.06
20	15.50	13.07	14.18	1.62	2.33	93.26	10.58	13.91	16.80	1.92	2.23	90.86	8.94	14.11	18.81	1.89	2.23	91.82
30	12.33	10.89	10.37	1.18	1.72	71.78	7.97	13.47	12.17	1.38	1.73	73.33	6.16	13.89	13.87	1.58	1.79	74.44
40	9.93	9.34	8.45	0.96	1.38	60.12	6.04	13.17	10.33	1.19	1.38	64.29	4.96	15.05	12.04	1.31	1.38	69.64
50	8.59	9.43	7.32	0.84	1.18	54.62	5.23	13.48	8.96	1.05	1.18	61.80	4.29	15.54	10.82	1.22	1.18	66.20
60	7.63	8.78	6.55	0.75	1.04	49.50	4.75	10.59	8.13	0.94	1.04	50.90	3.86	16.64	9.91	1.13	1.04	65.16
70	7.40	8.45	6.00	0.69	0.95	46.98	4.42	14.74	7.75	0.88	0.95	57.48	3.59	17.82	9.33	1.07	0.95	65.52
80	7.00	8.22	5.60	0.64	0.87	44.66	4.20	15.06	7.09	0.80	0.87	53.04	3.40	16.88	8.61	0.99	0.87	61.50
90	6.49	8.04	5.27	0.60	0.89	42.58	4.00	15.92	6.89	0.77	0.89	56.80	3.25	19.35	8.30	0.96	0.82	65.96
100	6.81	7.97	5.03	0.57	0.77	42.30	3.83	16.69	6.40	0.74	0.77	56.86	3.24	20.65	8.07	0.91	0.77	67.28
110	5.70	7.65	4.89	0.55	0.75	38.94	3.76	17.74	6.43	0.73	0.75	58.15	3.13	22.07	7.91	0.90	0.75	69.52
120	5.62	7.63	4.66	0.53	0.70	38.28	3.75	18.28	6.39	0.68	0.70	62.06	3.08	22.42	7.70	0.88	0.70	69.56



## APPENDIX F

### LABOUR-COSTS

If weighted average of labour requirement for various systems is determined for each acre per irrigation, two labour-hours are required.

By assuming that 650,000 acres are irrigated in Alberta, and by an average of two irrigations per season, then:

$$2 \times 2 = 4 \text{ labour-hours per season per irrigation}$$

$$650,000 \times 4 = 2,600,000$$

If labour wage is assumed as \$1.00 per hour, then:

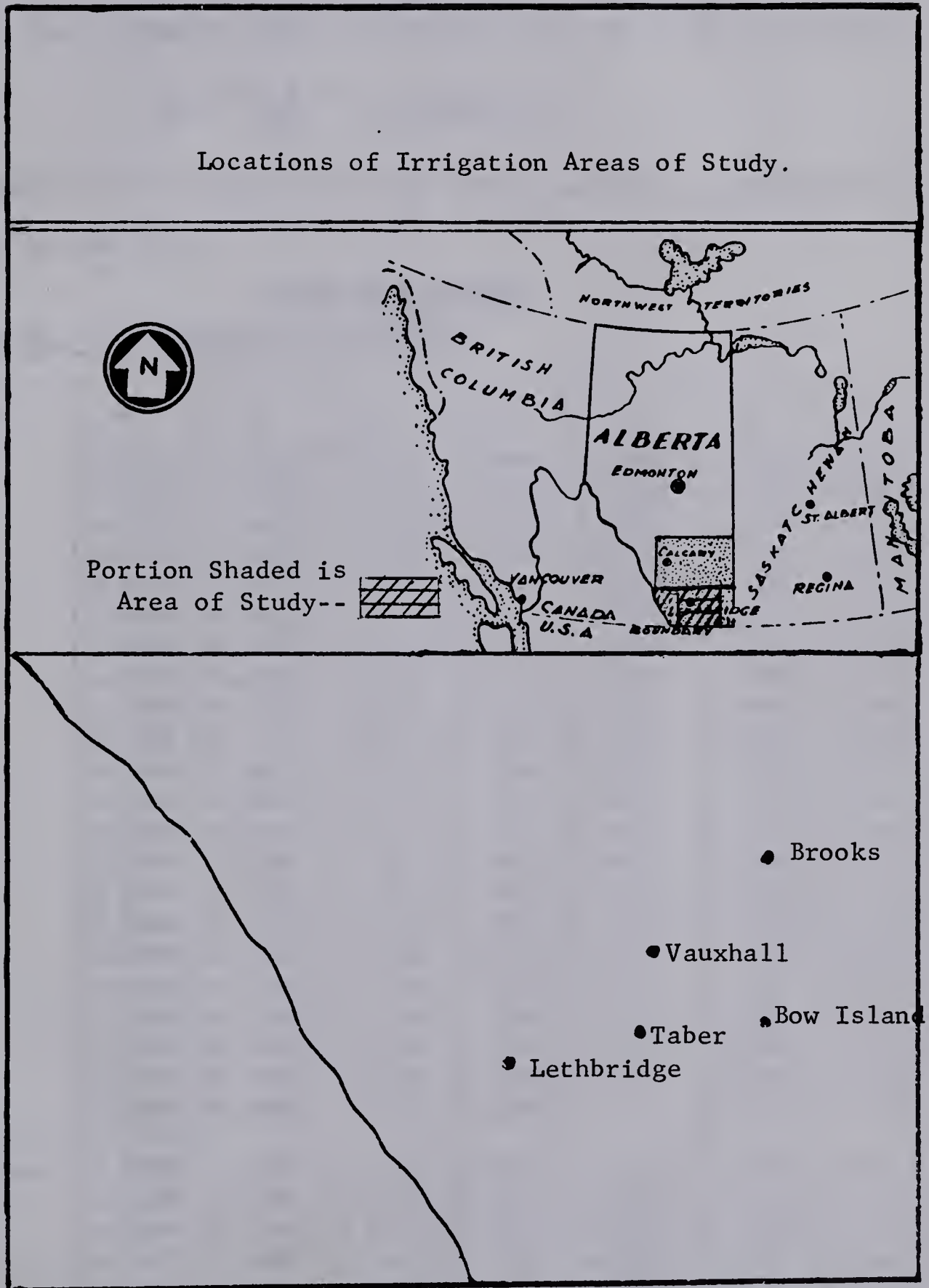
$$2,600,000 \times 1.00 = \$2,600,000 \text{ per year.}$$

This is only for Alberta. The figure will be more significant if cost of the irrigable areas of the world are considered.



APPENDIX G

Locations of Irrigation Areas of Study.





# APPENDIX H

## TABLES OF NORMAL TIMES

In the following tables the normal times are calculated from:

$$NT = \frac{OT \times R}{100} \quad (\text{in minutes})$$

Each pipe is 40 ft long with a four inch diameter, weighing 29.8 lb or 0.74 lb per foot.

### HAND-MOVE SYSTEM

Element No. 1: Pick-up and draining.

Crop	NT	NT	NT	NT	NT	NT	NT	NT
Flax	0.6500	0.6500	0.6500	0.6000	0.6000	0.6000	0.4800	0.4550
	0.4500	0.6000	0.6100	0.6100	0.6200	0.6000	0.6500	0.6500
	0.6500	0.6000	0.6500	0.6400	0.6500	0.6500	0.6500	0.6400
	0.6400	0.6500	0.6600	0.6500	0.6500	0.6500	0.6600	0.6490
	0.6490	0.6600	0.6490	0.6500	0.6400	0.6600	0.6600	0.6600
	0.6500	0.6400	0.6500	0.6500	0.6500	0.6500	0.6400	0.6500
	0.6500	0.6400	0.6500	0.6500	0.6600	0.6600	0.6300	0.6500
	0.2090	0.6000	0.3500	0.5160	0.4800	0.5500	0.4920	0.3000
	0.3100	0.3000	0.3000	0.3000	0.3100	0.3000	0.3000	0.3000
	0.3000	0.3150	0.2860	0.3000	0.2820	0.2800	0.3000	0.2860
	0.3000	0.3000	0.3150	0.3000	0.2760	0.3000	0.3010	0.3100
	0.3010	0.3000	0.3010	0.2890	0.3000	0.3000	0.2800	0.3000
	0.3000	0.3000	0.4200	0.4200	0.4400	0.4550	0.4800	0.4800
	0.4800	0.4500	0.4480	0.4800	0.4800	0.4550	0.4550	0.4800
	0.2000	0.1900	0.1980	0.2000	0.2000	0.2000	0.2000	0.2090
	0.2200	0.2100	0.2100	0.2200	0.1980	0.2090	0.1980	0.2100
	0.1980	0.1980	0.1980	0.2100	0.1920	0.1980	0.2100	0.2100
	0.2100	0.2100	0.2100	0.2100	0.2200	0.1980	0.2100	0.2200
	0.2100	0.2100	0.2100	0.1980	0.2100	0.2000	0.2100	0.2100
	0.2200	0.2100	0.2100	0.1980	0.1980	0.2090	0.1980	0.1980
	0.2100	0.1980	0.2100	0.2100	0.2100	0.2100	0.2100	0.2200
	0.2100	0.1900	0.2310	0.2280	0.2310	0.2200	0.2200	0.1090
Sugar Beet	0.1980	0.2200	0.2100	0.2090	0.2400	0.1980	0.2140	0.2140
	0.2140	0.2140	0.1920	0.2140	0.1920	0.2140	0.2140	0.1980
	0.1920	0.1760	0.1760	0.1610	0.1980	0.1430	0.1440	0.1760
	0.1800	0.1680	0.1560	0.1900	0.1680	0.1650	0.1800	0.1440
	0.1560	0.1400	0.1440	0.1440	0.1540	0.1650	0.1440	0.1540
	0.1320	0.1440	0.1540	0.1440	0.1320	0.1320	0.1320	0.1320



Crop	NT	NT	NT	NT	NT	NT	NT	NT
Sugar Beet	0.1560	0.1440	0.1540	0.1560	0.1200	0.1440	0.1320	0.1440
	0.6500	0.5500	0.6000	0.2400	0.2250	0.3000	0.3000	0.3000
	0.3000	0.3000	0.3000	0.3200	0.3200	0.4200	0.2700	0.2800
	0.3000	0.3000	0.3000	0.4550	0.3250	0.4550	0.4550	0.4400
	0.4550	0.4800	0.4550	0.4800	0.4550	0.4800	0.4760	0.5900
	0.5200	0.4500	0.4950	0.5400	0.4880	0.4800	0.4410	0.1800
	0.3200	0.0720	0.0750	0.0650	0.1200	0.1200	0.1200	0.1000
	0.1080	0.0980	0.0960	0.1170	0.0840	0.1200	0.8750	0.1200
	0.1200	0.0960	0.1200	0.1040	0.2160	0.0960	0.1100	0.1200
	0.0960	0.1200	0.1200	0.1200	0.1200	0.1320	0.1200	0.1200
	0.1200	0.1200	0.1200	0.1200	0.1200	0.1040	0.3800	0.1540
	0.1200	0.3000	0.3000	0.0840	0.0750	0.0650	0.1200	0.0780
	0.1320	0.1320	0.1200	0.0910	0.0780	0.0780	0.1320	0.2070
	0.1200	0.0895	0.1320	0.0875	0.0780	0.1320	0.1200	0.1200
	0.1320	0.1320	0.1200	0.1760	0.1200	0.0910	0.2160	0.1200
	0.1200	0.0910	0.1200	0.1200	0.0780	0.1200	0.0910	0.1320
	0.1000	0.1320	0.1200	0.1320	0.1320	0.1200	0.1200	0.1200
	0.1040	0.0780	0.0780	0.1200	0.1040	0.1040	0.1040	0.1200
	0.1320	0.1320	0.1320	0.1440	0.1320	0.1040	0.1320	0.1320
	0.1320	0.1760	0.1200	0.1320	0.1200	0.1320	0.1200	0.1320
	0.1200	0.1320	0.1320	0.1200	0.1320	0.1320	0.1320	0.1200
	0.1320	0.1320	0.1320	0.1200	0.1320	0.1760	0.1780	0.1200
	0.1760	0.1760	0.1760	0.1200	0.1200	0.1320	0.1200	0.1320
	0.1200	0.1200	0.1320	0.1320	0.1200	0.1320	0.1320	0.1320
	0.1200	0.2640	0.1970	0.1660	0.1600	0.2500	0.2000	0.3520
	0.1320	0.1320	0.3300	0.1650	0.2530	0.1600	0.1650	0.3000
	0.1540	0.1320	0.1780	0.1760	0.2600	0.1600	0.1650	0.3300
	0.1650	0.1700	0.1320	0.1320	0.1800	0.1600	0.1540	0.1540
	0.1800	0.1800	0.1800	0.1560	0.1446	0.2070	0.2430	0.1600
	0.1600	0.2500	0.2000	0.3200	0.3000	0.3000	0.5000	0.5000
	0.1780	0.3410	0.2500	0.1440	0.1400	0.1320	0.1040	0.1320
	0.1320	0.1760	0.2530	0.2530	0.2200	0.2500	0.2310	0.1680
	0.2000	0.1980	0.5000	0.5100	0.5100	0.5000	0.5100	0.5040
	0.5000	0.5000	0.6200	0.5610	0.0870	0.0990	0.0850	0.0960
	0.0960	0.0960	0.0960	0.0960	0.1080	0.0960	0.0960	0.0960
	0.0960	0.0960	0.0960	0.1320	0.1080	0.1200	0.0875	0.0960
	0.1320	0.4200	0.1560	0.1200	0.0960	0.1080	0.1320	0.0960
	0.0750	0.1320	0.0750	0.0960	0.0960	0.0960	0.0835	0.2200
	0.2400	0.3000	0.1920	0.2400	0.2200	0.1440	0.1320	0.1320
	0.1320	0.1200	0.0960	0.0960	0.0960	0.6600	0.1320	0.1320
	0.0750	0.2100	0.1320	0.3335	0.3480	0.1200	0.1320	0.1320
	0.1440	0.3480	0.1320	0.6050	0.5830	0.6160	0.6000	0.3640
	0.2250	0.4550	0.3000	0.4200	0.4200	0.3200	0.3200	0.3200
	0.5040	0.4200	0.3200	0.3280	0.4200	0.3600	0.4200	0.4800
	0.5100	0.3150	0.3000	0.3850	0.4200	0.3200	0.3500	0.3600
	0.4200	0.3200	0.3200	0.3440	0.3200	0.3200	0.3400	0.4000
	0.4675	0.4800	0.5000	0.4800	0.4880	0.3600	0.5400	0.4240



Crop	NT	NT	NT	NT	NT	NT	NT	NT
Sugar Beet	0.5220	0.3690	0.5490	0.4880	0.4200	0.3600	0.5310	0.5220
	0.3600	0.4500	0.4500	0.5000	0.4550	0.4000	0.4950	0.5040
	0.5400	0.4800	0.1440	0.1440	0.1320	0.1440	0.1320	0.1080
	0.1320	0.1320	0.1320	0.1320	0.1200	0.1320	0.1200	0.1320
Beans	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1440	0.1320
	0.1200	0.1320	0.1320	0.1200	0.1200	0.1440	0.1320	0.1200
	0.1320	0.1320	0.1200	0.1320	0.1320	0.1200	0.1320	0.1320
	0.1200	0.1320	0.1320	0.1320	0.1200	0.1320	0.1320	0.1320
Potato	0.1200	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1440
	0.1440	0.1440	0.1320	0.1320	0.1320	0.1440	0.1320	0.1320
	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320
	0.1200	0.1320	0.1800	0.3000	0.1200	0.1320	0.1430	0.1200
	0.1320	0.1440	0.1560	0.1760	0.3600	0.1200	0.1760	0.1920
	0.1680	0.1320	0.1320	0.1440	0.1920	0.1440	0.1920	0.1800
	0.1800	0.1760	0.1540	0.1800	0.1760	0.1440	0.1320	0.1320
	0.1320	0.1560	0.1540	0.1560	0.1870	0.1760	0.1540	0.1540
	0.1560	0.1560	0.1560	0.1320	0.1440	0.1320	0.1560	0.1320
	0.1540	0.1540	0.1440	0.1540	0.1650	0.1650	0.1760	0.1320
	0.1320	0.1540	0.1650	0.1320	0.1540	0.1320	0.1540	0.1320
	0.1430	0.1200	0.1320	0.1540	0.1320	0.1320	0.1540	0.1540
	0.1320	0.1540	0.1760	0.1540	0.1540	0.1560	0.1540	0.1680
	0.1540	0.1440	0.1540	0.1540	0.1080	0.1900	0.1750	0.2480
	0.2790	0.2100	0.2200	0.2200	0.2350	0.2140	0.2100	0.2100
	0.2520	0.2420	0.2640	0.2520	0.2645	0.2600	0.1320	0.1180
	0.1170	0.1040	0.1040	0.1430	0.1320	0.1320	0.1800	0.0910
	0.0945	0.1200	0.1430	0.2200	0.4440	0.1040	0.1900	0.1495
	0.2100	0.2200	0.2565	0.1080	0.1210	0.1500	0.1600	0.1200
	0.1900	0.1320	0.1440	0.1200	0.1430	0.1320	0.1200	0.1500
	0.1760	0.1540	0.1600	0.1250	0.1250	0.1430	0.1320	0.1760
	0.1650	0.1430	0.1540	0.1650	0.1540	0.1540	0.1430	0.1320
	0.1800	0.1320	0.1320	0.1540	0.1650	0.1320	0.1560	0.1560
	0.1680	0.1540	0.1320	0.1440	0.1320	0.1440	0.1650	0.1320
	0.1320	0.1320	0.1320	0.1320	0.1760	0.1200	0.1320	0.1320
	0.1320	0.1320	0.1440	0.1560	0.1100	0.0960	0.1125	0.0960
	0.0840	0.1320	0.0960	0.1200	0.1200	0.0880	0.1080	0.1440
Corn	0.1600	0.1200	0.0875	0.0875	0.1870	0.1200	0.1200	0.1200
	0.0960	0.1080	0.1320	0.0960	0.1080	0.0960	0.1080	0.1200
	0.1430	0.1200	0.1320	0.1080	0.1320	0.1200	0.0960	0.1200
	0.1320	0.1495	0.1320	0.3720	0.1540	0.1320	0.1080	0.1200
	0.2100	0.1540	0.1430	0.1200	0.1320	0.1200	0.1320	0.1320
	0.1200	0.1080	0.1320	0.1210	0.1430	0.1320	0.1100	0.1080
	0.1080	0.1200	0.1210	0.3600	0.3960	0.2750	0.1760	0.1980
	0.2600	0.1760	0.2280	0.1980	0.1920	0.1760	0.2200	0.1440
	0.2200	0.1760	0.1680	0.1300	0.1200	0.1430	0.1200	0.1320
	0.1920	0.1800	0.1430	0.2040	0.1200	0.1210	0.1560	0.1560



Crop	NT	NT	NT	NT	NT	NT	NT	NT
Corn	0.1430	0.1320	0.1440	0.1760	0.1920	0.1760	0.1920	0.1870
	0.1920	0.1870	0.1760	0.1760	0.1870	0.1540	0.1700	0.1430
	0.1540	0.1760	0.1760	0.1650	0.1760	0.1650	0.1650	0.1650
	0.1650	0.1650	0.1760	0.1920	0.1870	0.1760	0.1320	0.1430
	0.1430	0.1760	0.1210	0.1200	0.1200	0.1540	0.1320	0.1210
	0.1210	0.1200	0.1200	0.1320	0.1540	0.1080	0.1200	0.1200
	0.1320	0.1200	0.1200	0.1200	0.1320	0.1080	0.1200	0.1320
	0.1320	0.1320	0.1200	0.1200	0.1320	0.1200	0.1200	0.1200
	0.1200	0.1320	0.2160	0.1200	0.1320	0.1200	0.1320	0.1200
	0.1320	0.1200	0.1320	0.1200	0.1320	0.1320	0.1440	0.1320
	0.1200	0.1320	0.1320	0.1200	0.1320	0.1200	0.1320	0.1320
	0.1320	0.1320	0.4510	0.1440	0.1320	0.1320	0.2000	0.1760
Alfalfa	0.4100	0.3500	0.0960	0.0750	0.0910	0.0840	0.0960	0.1320
	0.0860	0.0780	0.0750	0.0960	0.0960	0.0960	0.0960	0.0960
	0.1080	0.1200	0.1200	0.1080	0.1080	0.1320	0.1200	0.1080
	0.1200	0.1320	0.1200	0.1320	0.1320	0.1320	0.1200	0.1320
	0.1320	0.1200	0.1200	0.1200	0.1200	0.1200	0.1320	0.1320
	0.1200	0.1200	0.1320	0.1200	0.0780	0.0780	0.0780	0.1320
	0.1200	0.1200	0.1320	0.1320	0.1200	0.1200	0.1320	0.1320
	0.1200	0.1200	0.1200	0.1200	0.1200	0.1200	0.1200	0.1320
	0.1200	0.1200	0.1200	0.1200	0.1440	0.1440	0.1440	0.1200
	0.1320	0.1320	0.1200	0.1200	0.1320	0.1200	0.1080	0.1080
	0.1320	0.1320	0.1320	0.1320	0.1320	0.1200	0.1320	0.1320
	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320
	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320
	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320
	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320
	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320
	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320
	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320
	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320
	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320
	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320
	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320
	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320
	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320
	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320
	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320
Element No. 2: Carrying pipe 60 ft.								
Sugar Beet	0.3840	0.3720	0.3720	0.3840	0.3840	0.3720	0.3840	0.3770
	0.3840	0.3840	0.4480	0.4180	0.4290	0.4290	0.4180	0.3840
	0.3840	0.3840	0.3720	0.3720	0.3720	0.3720	0.3250	0.3720
	0.3720	0.3720	0.3960	0.4080	0.3720	0.3840	0.3840	0.3840
	0.3840	0.3720	0.3720	0.3720	0.3720	0.3720	0.3840	0.3720
	0.3720	0.3840	0.3840	0.4360	0.4320	0.4200	0.4200	0.4080
	0.4200	0.4200	0.4180	0.4680	0.3840	0.3720	0.3720	0.3840
	0.3720	0.4290	0.4290	0.4290	0.3720	0.3720	0.3720	0.3720
	0.3960	0.3720	0.3600	0.3600	0.3600	0.3480	0.3980	0.3720
	0.3840	0.3840	0.3840	0.3840	0.3720	0.3720	0.3840	0.3840



Crop	NT	NT	NT	NT	NT	NT	NT	NT
Sugar Beet	0.3720	0.3720	0.3720	0.3840	0.3720	0.3600	0.3600	0.3600
	0.3480	0.3250	0.4560	0.3120	0.3240	0.3240	0.3480	0.3240
	0.3600	0.3380	0.3720	0.3720	0.3600	0.3720	0.3360	0.3480
	0.3480	0.3600	0.3600	0.3600	0.3480	0.3600	0.3600	0.3480
	0.3600	0.3140	0.4025	0.3910	0.3600	0.3480	0.3360	0.3360
	0.3850	0.3960	0.3960	0.3960	0.3960	0.3480	0.3600	0.3720
	0.3600	0.3480	0.3480	0.3480	0.3480	0.3480	0.3720	0.3720
	0.3600	0.4560	0.3360	0.3360	0.3720	0.3840	0.3360	0.3400
	0.3360	0.3480	0.3600	0.3600	0.3600	0.3480	0.3600	0.3850
	0.3480	0.3720	0.4560	0.3480	0.3840	0.4320	0.3960	0.3480
	0.3480	0.3480	0.3480	0.3600	0.3360	0.3360	0.3360	0.3480
	0.4320	0.4560	0.4080	0.4800	0.4080	0.4080	0.4080	0.4080
	0.4080	0.4080	0.4080	0.4320	0.4080	0.4080	0.4080	0.4080
	0.4080	0.4080	0.4560	0.4440	0.4080	0.4080	0.4080	0.4080
	0.4080	0.4080	0.4080	0.4080	0.4080	0.4080	0.4200	0.4200
	0.4200	0.4200	0.4200	0.4200	0.4280	0.3740	0.4280	0.4485
	0.4200	0.4200	0.4200	0.4400	0.4200	0.4200	0.4200	0.4200
	0.4200	0.4080	0.4080	0.4080	0.4200	0.4200	0.4200	0.4200
	0.3850	0.4080	0.4200	0.4800	0.4200	0.4200	0.4200	0.4080
	0.3720	0.3600	0.3960	0.3850	0.4000	0.4000	0.4000	0.4000
	0.4000	0.3960	0.4300	0.4300	0.4300	0.4000	0.3850	0.3850
	0.3720	0.3600	0.3720	0.3480	0.3480	0.3600	0.3600	0.3850
	0.3960	0.3840	0.3850	0.3720	0.3720	0.3720	0.3720	0.3720
	0.3960	0.4100	0.4000	0.4000	0.4100	0.4200	0.4100	0.4100
	0.4100	0.4200	0.4200	0.3720	0.3600	0.3720	0.3720	0.3720
	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720
	0.3600	0.3600	0.3720	0.3720	0.3720	0.3600	0.3720	0.3720
	0.3600	0.3720	0.3600	0.3720	0.3720	0.3720	0.3600	0.3720
	0.3720	0.3720	0.3720	0.4720	0.4560	0.4560	0.4560	0.4950
	0.4960	0.4950	0.4950	0.4950	0.4950	0.4620	0.4730	0.4950
	0.4680	0.4680	0.4800	0.4800	0.4560	0.4600	0.4440	0.4950
	0.4950	0.4950	0.4950	0.4680	0.4680	0.4560	0.4560	0.4560
	0.4680	0.4680	0.4680	0.4680	0.4550	0.4680	0.4680	0.4560
	0.4560	0.4560	0.4560	0.4560	0.4600	0.4600	0.4560	0.4560
	0.4550	0.4860	0.4680	0.4560	0.4560	0.4560	0.4560	0.4560
	0.4860	0.4680	0.5500	0.5500	0.4680	0.5320	0.4680	0.4680
	0.4680	0.4680	0.4800	0.4800	0.4800	0.4800	0.4680	0.4680
	0.4800	0.4800	0.5000	0.5100	0.4960	0.5000	0.5000	0.4860
Flax	0.2760	0.2860	0.3120	0.3850	0.4320	0.4320	0.4680	0.4680
	0.3960	0.3960	0.4380	0.4400	0.3900	0.4200	0.4300	0.4440
	0.4680	0.4400	0.3960	0.3960	0.3960	0.3850	0.3520	0.4320
	0.3900	0.3670	0.4320	0.4200	0.4200	0.4200	0.4300	0.4320
	0.4320	0.4680	0.4440	0.4320	0.4320	0.4290	0.4400	0.4680
	0.3600	0.3600	0.3600	0.3600	0.3600	0.3600	0.3600	0.3600
	0.4320	0.4320	0.4680	0.4320	0.3850	0.4200	0.4200	0.4200



Crop	NT	NT	NT	NT	NT	NT	NT	NT
Flax	0.3960	0.3960	0.4200	0.4200	0.4320	0.4440	0.4200	0.4560
	0.4320	0.4320	0.3600	0.3600	0.3600	0.3600	0.3600	0.3600
	0.3600	0.3600	0.3600	0.3600	0.3600	0.3600	0.3600	0.3600
	0.3600	0.3600	0.3600	0.3600	0.3600	0.3600	0.3600	0.3600
	0.3600	0.3600	0.3600	0.3600	0.3600	0.3600	0.3600	0.3600
	0.2750	0.3520	0.4080	0.3900	0.3120	0.4025	0.3120	0.4025
	0.4420	0.3900	0.4030	0.4290	0.3900	0.3900	0.4030	0.4290
	0.4030	0.4290	0.4030	0.4030	0.4030	0.3900	0.3770	0.3900
	0.4290	0.3770	0.4030	0.3960	0.3900	0.5500	0.4200	0.4030
	0.4550	0.3900	0.4500	0.4160	0.3900	0.3900	0.4160	0.4030
	0.3900	0.4500	0.4160	0.3900	0.3900	0.4160	0.3900	0.3900
	0.3510	0.4200	0.4030	0.3260	0.3770	0.3520	0.4000	0.4000
	0.4200	0.4200	0.3250	0.3770	0.3520	0.3480	0.3640	0.3250
	0.4200	0.4320	0.3900	0.3770	0.3900	0.3900	0.3770	0.3900
	0.3770	0.3770	0.3900	0.4200	0.4560	0.4200	0.3900	0.3190
	0.2750	0.2740	0.3960	0.3600	0.3250	0.4200	0.4200	0.3100
	0.3100	0.3190	0.3960	0.3600	0.3230	0.4200	0.4200	0.3900
Potato	0.3960	0.3900	0.4200	0.4200	0.3900	0.4031	0.4031	0.4280
	0.3960	0.3960	0.4680	0.4320	0.5200	0.4800	0.4680	0.4560
	0.4560	0.4680	0.4680	0.4550	0.4680	0.4560	0.4030	0.4680
	0.4680	0.4875	0.4860	0.4600	0.4680	0.4200	0.3900	0.3900
	0.3900	0.4000	0.3650	0.3600	0.4200	0.4680	0.3900	0.3900
	0.4300	0.4300	0.4300	0.3600	0.3600	0.3600	0.3600	0.4320
	0.4320	0.4320	0.4300	0.3600	0.3600	0.3600	0.3600	0.3600
	0.3900	0.4030	0.4080	0.4320	0.4320	0.4320	0.3900	0.3900
	0.4030	0.4080	0.4390	0.4390	0.4320	0.3900	0.3900	0.3900
	0.4030	0.3900	0.4200	0.3900	0.4320	0.4320	0.4320	0.4320
	0.3900	0.4320	0.4320	0.4320	0.4320	0.3900	0.4320	0.3900
	0.4080	0.4080	0.3900	0.3900	0.3900	0.3900	0.3900	0.3900
	0.4080	0.4080	0.3900	0.3900	0.3900	0.3900	0.4080	0.4080
	0.4080	0.4080	0.4080	0.4080	0.3900	0.3900	0.3900	0.4080
	0.4080	0.3900	0.4080	0.4080	0.4080	0.3900	0.3900	0.4080
	0.4080	0.3900	0.3900	0.3900	0.3900	0.3900	0.3900	0.3900
	0.3190	0.3600	0.3640	0.3380	0.3380	0.3300	0.3300	0.3300
	0.3720	0.3720	0.4290	0.3720	0.3840	0.3840	0.3940	0.3840
	0.3800	0.3740	0.3720	0.3720	0.3874	0.3720	0.3720	0.3720
	0.3720	0.3720	0.3720	0.3720	0.3600	0.4250	0.3874	0.3875
	0.3480	0.3720	0.3960	0.3960	0.3480	0.3720	0.4110	0.3600
	0.3600	0.3480	0.3480	0.3600	0.3600	0.3600	0.3600	0.3600
	0.4940	0.4125	0.4200	0.4080	0.3000	0.4200	0.4200	0.3850
	0.3850	0.3960	0.3850	0.3960	0.3960	0.4560	0.4200	0.4800
	0.4680	0.4200	0.4730	0.4730	0.4500	0.4200	0.4200	0.4320
	0.4180	0.4320	0.4320	0.4200	0.4200	0.3850	0.4200	0.4200
	0.4320	0.4320	0.4320	0.4200	0.4200	0.4200	0.4290	0.4320



Crop	NT	NT	NT	NT	NT	NT	NT	NT
Potato	0.4200	0.4200	0.4200	0.4200	0.4320	0.3850	0.3600	0.3600
	0.4200	0.3960	0.3630	0.4200	0.4200	0.4200	0.4200	0.4200
	0.4200	0.4200	0.4320	0.4200	0.4200	0.4200	0.4200	0.4200
	0.4200	0.4200	0.4200	0.4200	0.4320	0.4320	0.4320	0.4320
	0.4320	0.4320	0.4320	0.4320	0.4320	0.4320	0.4320	0.4320
	0.4200	0.4300	0.4200	0.4200	0.4200	0.4200	0.4200	0.4200
	0.4320	0.4320	0.4200	0.4200	0.4320	0.4200	0.4200	0.4320
	0.4200	0.4200	0.4320	0.4320	0.4320	0.4320	0.4320	0.4320
	0.4320	0.4320	0.4320	0.4320	0.4320	0.4320	0.4320	0.4320
	0.4320	0.4320	0.4320	0.4320	0.4320	0.4320	0.4320	0.4320
	0.4200	0.4320	0.4200	0.4200	0.4200	0.4320	0.4200	0.4320
	0.4290	0.3600	0.3600	0.3600	0.4100	0.3600	0.3480	0.3600
	0.3720	0.3720	0.3840	0.3720	0.3720	0.3720	0.3720	0.3720
	0.3840	0.3840	0.3720	0.4390	0.4390	0.4390	0.4390	0.4390
	0.4390	0.4390	0.4390	0.4390	0.4390	0.4390	0.4390	0.4390
	0.4390	0.4390	0.4390	0.4390	0.4390	0.4390	0.4390	0.4390
	0.3820	0.3820	0.3820	0.3820	0.3820	0.3820	0.3820	0.3720
	0.3172	0.3172	0.3820	0.3720	0.3720	0.3720	0.3720	0.3720
Sugar Beet	0.3840	0.3840	0.3720	0.3720	0.3720	0.3840	0.3720	0.3700
	0.3720	0.3720	0.3840	0.3840	0.3840	0.3840	0.3720	0.3720
	0.3720	0.3720	0.3720	0.3720	0.3840	0.3720	0.3720	0.3720
	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720
	0.3840	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720
	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720
	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720
	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720
	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720
	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720
	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720
	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720
	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720
	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720
	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720
	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720
	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720
Potato	0.5400	0.5400	0.5500	0.3630	0.3500	0.3500	0.3000	0.3600
	0.3000	0.3750	0.3000	0.3080	0.3000	0.3000	0.2750	0.4560
	0.4320	0.4400	0.6380	0.4400	0.4070	0.3600	0.3300	0.3850
	0.2900	0.3850	0.4290	0.4290	0.4180	0.4180	0.2750	0.2750
	0.2750	0.3080	0.2750	0.3000	0.2750	0.3000	0.3850	0.3850
	0.4180	0.4180	0.4200	0.3960	0.3850	0.3960	0.3960	0.3960
	0.3960	0.3960	0.3630	0.4000	0.4180	0.4320	0.4320	0.4320
	0.3850	0.3850	0.4100	0.4100	0.3940	0.3940	0.3940	0.3940
	0.3850	0.4180	0.3840	0.3840	0.4800	0.3030	0.4800	0.4800
	0.4560	0.4560	0.4560	0.4320	0.4560	0.4440	0.4320	0.4320
	0.4240	0.4240	0.4510	0.4510	0.4510	0.4510	0.4510	0.4510



Crop	NT	NT	NT	NT	NT	NT	NT	NT
Bean	0.5760	0.5760	0.5760	0.5760	0.5760	0.5760	0.5760	0.5760
	0.5880	0.5880	0.5760	0.5760	0.5760	0.5605	0.5605	0.6000
	0.5605	0.5605	0.5760	0.5760	0.5760	0.5980	0.5120	0.5120
	0.5625	0.5375	0.5375	0.5375	0.5760	0.5760	0.5760	0.6000
	0.6000	0.6000	0.5375	0.5500	0.8260	0.5375	0.6000	0.5400
	0.5250	0.5380	0.4800	0.4800	0.4680	0.5160	0.5160	0.5880
	0.5500	0.5160	0.5600	0.5040	0.5520	0.5160	0.5160	0.5160
	0.5160	0.5160	0.5500	0.5040	0.5160	0.5610	0.5160	0.5160
	0.4920	0.4560	0.4560	0.5160	0.5160	0.4800	0.4160	0.4920
	0.5500	0.4160	0.5750	0.4560	0.5160	0.5160	0.4560	0.4560
	0.5160	0.3975	0.5160	0.3750	0.3750	0.3750	0.3750	0.3750
Sugar Beet	0.4950	0.5060	0.4560	0.5200	0.4400	0.4084	0.5300	0.5610
	0.6000	0.6000	0.4290	0.3960	0.4440	0.4590	0.4400	0.4500
	0.4950	0.4950	0.4560	0.5200	0.5200	0.5200	0.5200	0.5200
	0.5200	0.5200	0.4400	0.4400	0.4680	0.4400	0.4680	0.4400
	0.4680	0.4680	0.4100	0.4200	0.4950	0.4950	0.5060	0.4730
	0.4950	0.4950	0.5280	0.5200	0.5000	0.4800	0.4180	0.5500
	0.4510	0.4050	0.5830	0.3720	0.5610	0.3600	0.5060	0.3720
	0.4200	0.5500	0.5000	0.5520	0.4900	0.4900	0.4560	0.5000
	0.4560	0.5500	0.4400	0.5280	0.4680	0.3500	0.3720	0.3720
	0.4400	0.4400	0.4506	0.4620	0.4800	0.4920	0.4920	0.4680
	0.4220	0.4920	0.4506	0.4560	0.4600	0.4900	0.4900	0.4680
	0.3840	0.3720	0.3720	0.3720	0.3720	0.3600	0.3600	0.3600
	0.3720	0.3600	0.3720	0.3720	0.3720	0.3720	0.3720	0.3720
	0.3720	0.4680	0.4680	0.4800	0.4680	0.4800	0.4680	0.4680
	0.4680	0.4800	0.4800	0.4800	0.4800	0.5160	0.4680	0.4680
	0.4680	0.4680	0.4800	0.4800	0.4800	0.4680	0.4680	0.4680
	0.4680	0.4680	0.4680	0.4800	0.4800	0.4680	0.4680	0.4680
	0.4680	0.4800	0.4680	0.4680	0.4800	0.4680	0.4680	0.4800
	0.4000	0.5000	0.5060	0.4200	0.4400	0.3960	0.4200	0.4200
	0.4200	0.4400	0.4400	0.4080	0.4200	0.4200	0.4080	0.5000
	0.4950	0.6000	0.6000	0.5000	0.5125	0.3900	0.3960	0.3960
	0.3960	0.5500	0.5500	0.4950	0.4800	0.4800	0.4800	0.4800
Element No. 3: Connection								
Flax	0.2000	0.2000	0.1560	0.1560	0.1680	0.1680	0.1680	0.1680
	0.1560	0.1920	0.2200	0.1560	0.1540	0.1560	0.1680	0.1560
	0.1680	0.1560	0.1680	0.1560	0.1560	0.1680	0.1680	0.1560
	0.1560	0.1680	0.1680	0.1680	0.1680	0.1680	0.1560	0.1560
	0.1680	0.1560	0.1560	0.1560	0.1680	0.1560	0.1560	0.1560
	0.1560	0.1560	0.2000	0.1760	0.1760	0.1760	0.1760	0.1760
	0.1760	0.1760	0.1760	0.1760	0.1760	0.1680	0.1560	0.1560
Potato	0.1200	0.2000	0.2000	0.1680	0.1680	0.1680	0.1560	0.1440
	0.1320	0.1760	0.2080	0.1320	0.1200	0.1170	0.1430	0.2160



Crop	NT	NT	NT	NT	NT	NT	NT	NT
Potato	0.1200	0.1760	0.1890	0.1890	0.1780	0.1780	0.1870	0.1560
	0.1760	0.1760	0.1560	0.1440	0.1870	0.1870	0.1760	0.1780
	0.1320	0.1870	0.1440	0.1560	0.1870	0.1870	0.1760	0.1760
	0.1440	0.1440	0.1440	0.1870	0.1900	0.1800	0.1440	0.1320
	0.1440	0.1760	0.1900	0.1650	0.1900	0.1560	0.2090	0.1900
	0.1320	0.2000	0.2000	0.2000	0.2400	0.1200	0.2000	0.2000
	0.1820	0.1760	0.2000	0.2000	0.2000	0.1560	0.2100	0.1760
	0.1760	0.1760	0.1320	0.1760	0.1760	0.1320	0.1760	0.1760
	0.1870	0.1870	0.1870	0.1870	0.1440	0.1900	0.2000	0.1760
	0.1900	0.1860	0.1760	0.1900	0.1440	0.2000	0.1760	0.1760
	0.1760	0.1760	0.1320	0.1760	0.1870	0.1900	0.1200	0.1900
	0.2000	0.1760	0.1440	0.1760	0.1760	0.2000	0.2000	0.2000
	0.2000	0.1760	0.2000	0.1760	0.1760	0.2000	0.2000	0.2000
	0.2000	0.1760	0.2000	0.1760	0.1760	0.2000	0.2000	0.2000
Flax	0.2000	0.3000	0.2140	0.2000	0.1440	0.1760	0.1430	0.1680
	0.1560	0.1440	0.1760	0.1760	0.1560	0.1440	0.1560	0.1440
	0.1440	0.1560	0.1300	0.1440	0.1560	0.1560	0.1760	0.1440
	0.1440	0.1440	0.1440	0.1650	0.1440	0.1560	0.1560	0.1440
	0.1560	0.1440	0.1560	0.1560	0.1440	0.1440	0.1320	0.1440
	0.1560	0.1440	0.1440	0.1440	0.1560	0.1440	0.1440	0.1560
	0.1440	0.1560	0.1560	0.1170	0.1320	0.1560	0.1440	0.1440
	0.1320	0.1440	0.1560	0.1540	0.1560	0.1170	0.1440	0.1320
Potato	0.1750	0.1750	0.2000	0.1500	0.1300	0.1760	0.1680	0.1560
	0.2070	0.1100	0.1760	0.1800	0.1440	0.1856	0.1760	0.1870
	0.1760	0.1680	0.1760	0.1680	0.1800	0.1870	0.1900	0.1920
	0.1920	0.1920	0.1920	0.1760	0.1900	0.1920	0.1820	0.1920
	0.2040	0.2200	0.2000	0.1840	0.1680	0.1800	0.1880	0.1800
Sugar Beet	0.2400	0.1600	0.1080	0.1200	0.2070	0.1200	0.2400	0.1800
	0.1430	0.1620	0.1320	0.1200	0.1200	0.1200	0.1200	0.1320
	0.1800	0.1680	0.1980	0.1500	0.1500	0.1800	0.1800	0.2000
	0.2000	0.1300	0.1650	0.1680	0.1680	0.1430	0.1560	0.1680
	0.1680	0.1680	0.1680	0.1440	0.1440	0.1440	0.1440	0.1440
	0.1560	0.1560	0.1600	0.1100	0.1320	0.2100	0.1920	0.1920
	0.1200	0.2090	0.1560	0.1320	0.1320	0.1560	0.1980	0.1320
	0.1320	0.1650	0.1320	0.1800	0.1650	0.1200	0.1200	0.1320
	0.1320	0.1200	0.1040	0.1200	0.1200	0.1320	0.1540	0.1650
	0.1560	0.1650	0.1320	0.1320	0.1320	0.1200	0.1320	0.2000
	0.1040	0.1320	0.1780	0.1320	0.1320	0.1040	0.1040	0.1200
	0.1320	0.1320	0.1320	0.1760	0.1760	0.1320	0.1780	0.1780
	0.1760	0.1760	0.1320	0.1320	0.1440	0.1440	0.1320	0.1320
	0.1320	0.1760	0.1760	0.1200	0.1320	0.1320	0.1320	0.1320
	0.1320	0.1320	0.1320	0.1200	0.1320	0.1320	0.1200	0.1200
	0.1200	0.1320	0.1320	0.1200	0.1320	0.1320	0.1200	0.1200
	0.1320	0.1320	0.1320	0.1320	0.1320	0.0910	0.0910	0.1200
	0.1320	0.1320	0.1320	0.1320	0.1440	0.1440	0.1440	0.1320



Crop	NT	NT	NT	NT	NT	NT	NT	NT
Sugar Beet	0.1320	0.1320	0.1320	0.1760	0.1560	0.1760	0.1760	0.1560
	0.1250	0.1320	0.1320	0.1320	0.1320	0.1680	0.1560	0.1650
	0.1920	0.1560	0.1760	0.1560	0.1540	0.1640	0.1560	0.1760
	0.1760	0.1560	0.1560	0.1680	0.1320	0.1560	0.1760	0.1800
	0.1560	0.1760	0.1760	0.1760	0.1760	0.1760	0.1760	0.1760
	0.1560	0.1760	0.1760	0.1560	0.1250	0.1560	0.1560	0.1360
	0.1760	0.1560	0.1440	0.1440	0.1560	0.1560	0.1375	0.1760
	0.1375	0.1200	0.1760	0.1760	0.1650	0.1200	0.1200	0.1200
	0.1200	0.1370	0.1560	0.1760	0.1440	0.1250	0.1560	0.1980
	0.2090	0.2200	0.1200	0.1320	0.1125	0.1600	0.1600	0.1200
	0.1200	0.1760	0.1320	0.1200	0.1200	0.1200	0.1500	0.1320
	0.1670	0.1320	0.1380	0.1440	0.1200	0.1200	0.1200	0.1416
	0.1200	0.1200	0.1200	0.1320	0.1320	0.1650	0.1080	0.1800
Beans	0.1430	0.1080	0.1320	0.1610	0.1320	0.1900	0.1540	0.1320
	0.1440	0.1320	0.1540	0.1320	0.1320	0.1320	0.0960	0.1320
	0.1380	0.1320	0.1540	0.1440	0.1440	0.1080	0.1440	0.1440
	0.1495	0.1430	0.1800	0.1540	0.1920	0.1320	0.1320	0.1320
	0.1750	0.2200	0.2600	0.1870	0.1680	0.1600	0.1500	0.1500
Potato	0.1100	0.1870	0.1890	0.1440	0.1760	0.1780	0.1760	0.1900
	0.1760	0.1920	0.1800	0.1920	0.1960	0.1760	0.1760	0.1540
	0.1680	0.1560	0.1680	0.1560	0.2150	0.2000	0.2070	0.1560
	0.1440	0.1560	0.1440	0.1900	0.1760	0.1560	0.1760	0.1920
	0.1680	0.1680	0.2200	0.1850	0.1900	0.1560	0.2100	0.1680
	0.1560	0.1760	0.1650	0.1680	0.1760	0.1800	0.1760	0.1920
	0.1870	0.1760	0.1800	0.1920	0.1920	0.3000	0.1070	0.1320
Sugar Beet	0.1320	0.1320	0.1320	0.1440	0.1320	0.1320	0.1540	0.1320
	0.1320	0.1320	0.1440	0.1320	0.1320	0.1320	0.1320	0.1320
	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1760	0.1870
	0.1870	0.1760	0.1760	0.1320	0.1210	0.1210	0.1210	0.1320
	0.1210	0.1320	0.1320	0.1440	0.1320	0.1320	0.1320	0.1320
	0.1320	0.1760	0.1760	0.1760	0.1880	0.1870	0.1870	0.1870
	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320
	0.1320	0.1320	0.1760	0.1760	0.1320	0.1320	0.1760	0.1760
	0.1760	0.1760	0.1760	0.1320	0.1320	0.1440	0.1440	0.1540
	0.1440	0.1440	0.1440	0.1430	0.1440	0.1540	0.1560	0.1440
Potato	0.1440	0.1440	0.1560	0.1540	0.1440	0.1440	0.1440	0.1540
	0.1440	0.1440	0.1440	0.1440	0.1440	0.1440	0.1440	0.1440
	0.1400	0.1560	0.1440	0.1440	0.1440	0.1560	0.1440	0.1440
	0.1560	0.1560	0.1440	0.1440	0.1320	0.1320	0.1440	0.1360
	0.1440	0.1440	0.1560	0.1440	0.1440	0.1440	0.1450	0.1440
	0.1440	0.1440	0.1440	0.1440	0.1440	0.1440	0.1540	0.1440
	0.1440	0.1440	0.1560	0.1440	0.1560	0.1440	0.1440	0.1440
	0.1440	0.1540	0.1560	0.1440	0.1440	0.1560	0.1440	0.1440
	0.1440	0.1440	0.1440	0.1440	0.1440	0.1400	0.1440	0.1560



Crop	NT	NT	NT	NT	NT	NT	NT	NT
Flax	0.1080	0.1560	0.2530	0.2920	0.2060	0.2000	0.2100	0.2000
	0.1320	0.2200	0.1850	0.1920	0.1300	0.1680	0.1320	0.1320
	0.1440	0.1560	0.1540	0.1300	0.1400	0.1050	0.1320	0.0960
	0.1820	0.1540	0.2800	0.1800	0.1440	0.1200	0.1430	0.1430
	0.1495	0.1320	0.1210	0.1760	0.1980	0.1540	0.1900	0.1650
Potato	0.1540	0.1800	0.1920	0.1760	0.1900	0.1540	0.1650	0.1760
	0.1800	0.1540	0.2380	0.1440	0.1320	0.1320	0.1440	0.1430
	0.1650	0.1680	0.1680	0.1560	0.1760	0.1440	0.1440	0.1440
	0.1320	0.1440	0.1560	0.1560	0.1440	0.1440	0.1560	0.1920
	0.1440	0.1440	0.1440	0.1540	0.1440	0.1440	0.1440	0.1560
	0.1440	0.1500	0.1440	0.1440	0.1440	0.1440	0.1440	0.1560
	0.1560	0.1300	0.1300	0.1440	0.1440	0.1200	0.1440	0.1500
Flax	0.1600	0.1760	0.1800	0.1540	0.1650	0.1440	0.1440	0.1560
	0.1320	0.1560	0.1680	0.1920	0.2200	0.1800	0.1880	0.1920
	0.1440	0.1500	0.2200	0.1440	0.1440	0.1680	0.1440	0.0960
	0.1320	0.1400	0.2310	0.1560	0.1560	0.1560	0.1800	0.1400
	0.1760	0.1650	0.1900	0.1800	0.200	0.1440	0.1760	0.1540
	0.1560	0.1560	0.1560	0.1540	0.1800	0.1920	0.1560	0.1680
	0.1440	0.1440	0.1560	0.1650	0.1760	0.1320	0.1320	0.1250
	0.1320	0.1560	0.1440	0.1320	0.1650	0.1650	0.1650	0.1650
	0.1200	0.1430	0.1440	0.1300	0.1340	0.1430	0.1430	0.1320
	0.1440	0.1440	0.1560	0.1560	0.1440	0.1440	0.1540	0.1440
	0.1440	0.1440	0.1440	0.1560	0.1440	0.1320	0.1320	0.1690
	0.1440	0.1440	0.1440	0.1320	0.1440	0.1440	0.1444	0.1540
	0.1540	0.1560	0.1560	0.1540	0.1430	0.1560	0.1540	0.1540
	0.1440	0.1440	0.1540	0.1440	0.1540	0.1320	0.1540	0.1540
	0.1440	0.1440	0.1440	0.1440	0.1440	0.1440	0.1440	0.1440
	0.1560	0.1440	0.1440	0.1560	0.1440	0.1440	0.1440	0.1440
	0.1400	0.1440	0.1440	0.1440	0.1440	0.1760	0.1560	0.1540
Sugar Beet	0.1540	0.1540	0.1650	0.1560	0.1300	0.1560	0.1560	0.1560
	0.1440	0.1560	0.1680	0.1560	0.1870	0.1980	0.1560	0.1560
	0.1560	0.1560	0.1560	0.1560	0.1560	0.1560	0.1560	0.1680
	0.1680	0.1980	0.1680	0.1680	0.1560	0.1560	0.1560	0.1560
	0.1560	0.1560	0.1560	0.1560	0.1560	0.1560	0.1560	0.1560
	0.1560	0.1560	0.1560	0.1560	0.1560	0.1560	0.1560	0.1560
	0.1560	0.1560	0.1560	0.1560	0.1560	0.1560	0.1560	0.1560
	0.1560	0.1560	0.1560	0.1560	0.1560	0.1560	0.1560	0.1560
	0.1560	0.1560	0.1560	0.1320	0.1320	0.1320	0.1200	0.1320
	0.1320	0.1440	0.1800	0.1320	0.1320	0.1320	0.1440	0.1320
	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320
	0.1760	0.1320	0.1320	0.1320	0.1320	0.1320	0.1440	0.1320
	0.1320	0.1320	0.1440	0.1760	0.1760	0.1320	0.1440	0.1440
	0.1320	0.1200	0.1320	0.1320	0.1540	0.1440	0.1440	0.1320
	0.1320	0.1440	0.1560	0.1760	0.1870	0.1760	0.1760	0.2000



Crop	NT	NT	NT	NT	NT	NT	NT	NT
Sugar Beet	0.2000	0.2000	0.2000	0.1760	0.1760	0.1760	0.1320	0.1320
	0.1440	0.1200	0.1000	0.1125	0.1760	0.1760	0.1320	0.1320
	0.1000	0.1200	0.1000	0.1200	0.1125	0.1125	0.1320	0.1320
	0.1200	0.1440	0.1320	0.1980	0.2750	0.2400	0.1560	0.1560
	0.1560	0.1725	0.1560	0.1800	0.2000	0.2760	0.1360	0.1680
	0.1680	0.2400	0.2280	0.1800	0.1920	0.1300	0.1300	0.1680
	0.1320	0.1440	0.1560	0.1320	0.1320	0.1320	0.1320	0.1320
	0.1320	0.1320	0.1650	0.1320	0.1560	0.1760	0.1320	0.2200
	0.1320	0.1680	0.1320	0.1650	0.1200	0.1560	0.1500	0.1560
	0.1680	0.1980	0.1980	0.1980	0.1100	0.1440	0.1320	0.1320
	0.1680	0.1320	0.1680	0.1320	0.1680	0.1680	0.1680	0.1680
	0.2080	0.1680	0.1800	0.1300	0.1560	0.2185	0.1200	0.1560
	0.1080	0.1680	0.1200	0.1680	0.0960	0.1200	0.1320	0.1320
	0.1320	0.2530	0.1320	0.1320	0.1200	0.1320	0.1320	0.1320
	0.1760	0.1440	0.1320	0.1320	0.1560	0.1440	0.1560	0.1440
	0.1440	0.1440	0.2000	0.1170	0.1840	0.1320	0.1320	0.1870
	0.1495	0.2400	0.0910	0.1200	0.2000	0.1760	0.1760	0.2000
	0.1200	0.1200	0.1200	0.1320	0.1320	0.1320	0.1780	0.1760
	0.1320	0.1000	0.1000	0.1000	0.1320	0.1320	0.1320	0.1760
	0.1760	0.1760	0.1760	0.1320	0.1320	0.1320	0.1320	0.1040
	0.1040	0.1320	0.2000	0.2000	0.1760	0.1760	0.1760	0.1320
	0.1320	0.1760	0.1760	0.1320	0.1760	0.1320	0.1320	0.1320
	0.1320	0.1760	0.1760	0.1760	0.1760	0.1760	0.1200	0.1200
	0.1320	0.1320	0.1200	0.1320	0.1320	0.1760	0.1320	0.1870
	0.1870	0.1870	0.1760	0.1320	0.1200	0.1320	0.1200	0.1320
	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320	0.1320
	0.1760	0.1870	0.1760	0.1760	0.1760	0.1320	0.1320	0.1320
	0.1320	0.1320	0.1760	0.1760	0.1760	0.1650	0.1320	0.1320
	0.1320	0.1320	0.1760	0.1760	0.1760	0.1760	0.1760	0.1320
	0.1320	0.1200	0.1080	0.1080	0.1320	0.1320	0.1320	0.1200
	0.1200	0.1200	0.1200	0.1320	0.1320	0.1440	0.1320	0.1320
	0.1320	0.1780	0.1760	0.1760	0.1760	0.1760	0.1760	0.1760
	0.1760	0.1780	0.1760	0.1780	0.1780	0.1780	0.1780	0.1780
	0.1650	0.1650	0.1650	0.1560	0.1650	0.1650	0.1650	0.1650
	0.1760	0.1780	0.1760	0.1760	0.1800	0.1680	0.1440	0.1760
	0.1760	0.1760	0.1870	0.1870	0.1760	0.1760	0.1870	0.1870



GRAVITY

<u>Element No. 1: Put Canvas in the ditch (two men)</u>								
	NT	NT	NT	NT	NT	NT	NT	NT
	0.6000	0.4300	0.5900	0.6000	0.7000	0.7000	0.7000	0.7250
	0.7000	0.6000	0.7000	0.7000	0.5600	0.7000	0.7000	0.7000
<u>Element No. 2: Carrying the canvas about 95 ft.</u>								
	0.9200	0.8000	0.8000	0.7500	0.7500	0.7000	0.8000	0.8000
<u>Element No. 3: Passing a rod through the canvas (two men)</u>								
	0.5400	0.5000	0.6000	0.4500	0.6000	0.5500	0.5500	0.5000
<u>Element No. 4: Take the canvas out of old position (two men)</u>								
	0.3000	0.3000	0.6000	0.3600	0.3000	0.5500	0.6000	0.5000
	0.3800	0.3000	0.6000	0.6000	0.3000	0.5000	0.6000	0.5000
	0.6000	0.6000	0.6000	0.3800	0.6000	0.6000	0.5000	0.5000



Description	NT	NT	NT	NT	NT	NT	NT	NT
Turn off the motor	0.4560	0.4800	0.6500	0.5200	0.5260	0.4272	0.3000	0.7200
	0.3800	0.5600	0.7000	0.4560	0.5800	0.2800	0.4000	0.6000
	0.1800	0.1800	0.1800	0.4000	0.4000	0.3600	0.4000	0.6300
	0.2820	0.2800	0.3700	0.4000	0.4000	0.4000	0.4000	0.3860
	0.3760	0.3760	0.3600	0.3200	0.3000	0.4000	0.4000	0.5160
	0.5100	0.3600	0.3800	0.3800	0.4000	0.3700	0.3600	0.3800
	0.4500	0.4000	0.3760	0.3000	0.3200	0.2700	0.3000	0.3100
	0.3600	0.3600	0.3700	0.3800	0.4000	0.4000	0.4200	0.3600
	0.4100	0.3800	0.3760	0.3760	0.3760	0.3800	0.3800	0.4000
	0.3860	0.3860	0.4100	0.4000	0.4000	0.4000	0.4100	0.3860
Close elbow valve	0.4800	0.4000	0.6600	0.6000	0.4800	0.4800	0.4000	0.6000
	0.4800	0.6000	0.6000	0.5370	0.4800	0.6000	0.6000	0.4800
	0.4800	0.4800	0.6000	0.6000	0.4800	0.4800	0.4800	0.4800
	0.6000	0.6000	0.6000	0.4800	0.6000	0.4800	0.6000	0.4800
	0.4800	0.4800	0.4800	0.4800	0.4000	0.6000	0.6000	0.6000
	0.4800	0.4800	0.4800	0.4800	0.4800	0.4800	0.4800	0.6000
	0.4800	0.4800	0.4800	0.4800	0.4800	0.4800	0.4800	0.4800
Disconnection of first pipe	0.4800	0.3300	0.7900	0.5400	0.4200	0.3600	0.3000	0.2520
	0.4200	0.4200	0.3300	0.5200	0.5400	0.4300	0.3000	0.2520
	0.4200	0.3600	0.5000	0.4900	0.3600	0.3600	0.2500	0.3900
	0.4200	0.4100	0.5000	0.5000	0.4000	0.3800	0.4000	0.3800
Pushing the ring around the pipe	0.3600	0.3600	0.5400	0.9000	0.3600	0.1320	0.6000	0.9120
	0.3000	0.3000	0.4800	0.3600	0.1320	0.1220	0.6000	0.5600
	0.3000	0.4000	0.4000	0.3600	0.3600	0.3600	0.5000	0.5600
	0.3800	0.4000	0.4000	0.5000	0.6000	0.3800	0.3800	0.3000
Carry the support	0.4300	0.4000	0.9500	0.5100	0.3000	0.5400	0.9000	0.4000
	0.4000	0.5000	0.3800	0.4000	0.4100	0.5000	0.4000	0.4000
	0.3600	0.3000	0.5100	0.4320	0.1920	0.4000	0.4320	0.3800
	0.3600	0.3000	0.3000	0.4100	0.4500	0.4000	0.5100	0.5000
Connection of valve	0.2750	0.1560	0.2750	0.1430	0.1500	0.1920	0.2200	0.1920
	0.2750	0.3000	0.3000	0.6120	0.1800	0.2840	0.3000	0.1650
	0.6000	0.3000	0.6120	0.1980	0.2850	0.2000	0.3000	0.2180
Carry a 20' pipe for 30'	0.4950	0.5500	0.4200	0.5100	0.4400	0.4100	0.0400	0.0400
	0.3900	0.5000	0.4100	0.4100	0.4200	0.3600	0.4000	0.4000
	0.3900	0.5000	0.4100	0.4000	0.3800	0.3000	0.5000	0.3800
Laydown the first pipe	0.4950	0.5400	0.4000	0.5000	0.1080	0.5000	0.4800	0.4100
	0.3900	0.5600	0.4100	0.4000	0.2000	0.4200	0.4000	0.4000
	0.3800	0.5100	0.5000	0.4100	0.2100	0.4100	0.3900	0.4000



Description	NT	NT	NT	NT	NT	NT	NT	NT
Walk 1/4 mile to the middle of the system	4.1000 4.1000	4.7330 3.6000	5.2880 2.7900	7.5000 3.3000	4.8000 3.5000	5.3000 3.6000	5.6700 3.6000	11.4000 2.9000
Take cover off mover	0.1100 0.1800 0.1100	0.1000 0.1500 0.1920	0.2400 0.2200 0.1920	0.1100 0.1920 0.1920	0.1920 0.1900 0.1920	0.1220 0.1200 0.1220	0.1920 0.1920 0.1220	0.1800 0.1800 0.1800
Start mover engine	0.3990 0.1000 0.3000	0.6000 0.6007 0.6000	0.1200 0.3900 0.3900	0.5985 0.1800 0.1200	0.3990 0.1320 0.2200	0.4030 0.4030 0.2000	0.1995 0.4806 0.4000	0.1320 0.1900 0.3000
System moves 60'	4.4955 2.8020	2.8700 3.6565	6.6024 3.0000	2.3760 2.3760	2.5887 3.0000	2.6052 2.2000	3.6700 2.6000	2.5485 3.0000
Replace cap	0.1200 0.0800	0.1300 0.1325	0.1400 0.1200	0.1200 0.1300	0.1325 0.1200	0.1200 0.1200	0.1200 0.1300	0.1200 0.1300
Pull first pipe back	0.3000 0.3000	0.2400 0.2400	0.2400 0.2400	0.4100 0.4000	0.5160 0.2000	0.2000 0.3000	0.3600 0.5000	0.5400 0.2000
Support the wood	0.2600 0.2600 0.6000	0.5160 0.4000 0.6000	0.4000 0.3800 0.6000	0.4000 0.3800 0.4000	0.5000 0.6000 0.5000	0.3000 0.6000 0.5000	0.4000 0.6000 0.5000	0.5000 0.6000 0.6000
Carry ring to the middle of first pipe and tighten	0.4800 0.3900	0.3800 0.4000	0.4200 0.4000	0.4800 0.4100	0.4900 0.4000	0.4000 0.4000	0.7200 0.7000	0.4000 0.4000
Open the valve	0.6960 0.3000	0.3000 0.4000	0.6960 0.5300	0.5320 0.5000	0.3900 0.2800	0.1800 0.1300	0.1200 0.1200	0.1200 0.1200
Start motor	0.4200 0.3000	0.3100 0.4000	0.4257 0.4000	0.6700 0.3900	0.3000 0.3000	0.6000 0.4000	0.3100 0.3000	0.3000 0.4000
Priming the pump by hand	1.2000 1.3000	1.3650 1.4000	1.3650 1.3000	1.2000 1.2000	1.3650 1.3600	1.2000 1.2000	1.3000 1.3000	1.1800 1.2000
Regulate the motor	0.4920 0.3100	0.4000 0.5000	0.5500 0.3000	0.3600 0.4100	0.3000 0.3000	0.4000 0.1200	0.3000 0.1200	0.1200 0.1200
Check oil, water	0.2310 0.4000	0.8000 0.5000	0.5400 0.5000	0.4000 0.5000	0.5000 0.6000	0.5000 0.4900	0.5000 0.5000	0.5000 0.5000



Description	NT	NT	NT	NT	NT	NT	NT	NT
Regulating the Pressure	0.9600	0.9800	0.9000	0.8800	1.0000	0.8700	0.9600	0.9000
	0.8800	0.9800	0.9000	0.8500	1.0000	0.8000	0.8000	0.8100
	1.0000	0.9700	0.9700	0.8500	0.8500	0.9600	0.7000	0.8000
	0.9700	0.9700	0.8000	0.8500	0.8500	0.9600	0.8000	0.8100
	0.8000	0.9600	0.9600	0.8100	0.8100	0.8100	0.8100	0.8100
Stopping the engine	0.6000	0.6200	0.5920	0.6100	0.6300	0.6000	0.7000	0.6800
	0.5000	0.5000	0.3000	0.4300	0.3600	0.7000	0.6800	0.3400
	0.3800	0.5000	0.5000	0.5000	0.3900	0.6000	0.5100	0.3900
	0.3850	0.3960	0.4000	0.4100	0.4260	0.5000	0.5100	0.4100
	0.5100	0.6100	0.6000	0.5100	0.6000	0.6000	0.5600	0.5600
Starting the engine	0.3000	0.3100	0.3000	0.3900	0.3000	0.3000	0.3100	0.3100
	0.3200	0.3100	0.3100	0.3100	0.3100	0.3200	0.3200	0.3200
	0.3000	0.3000	0.3000	0.3000	0.3000	0.3200	0.2850	0.2900
Checking oil of the engine	0.2500	0.2600	0.2500	0.3000	0.4000	0.3300	0.2800	0.2850
	0.2700	0.2900	0.3000	0.2900	0.3000	0.2800	0.2850	0.3000
	0.3000	0.2900	0.3000	0.3000	0.3000	0.3000	0.2800	0.3000
Adding oil	0.2400	0.3000	0.3000	0.2500	0.2800	0.3100	0.3100	0.2600
	0.2600	0.2100	0.3300	0.2900	0.3000	0.3100	0.3000	0.2800
	0.2700	0.2500	0.2600	0.2800	0.2900	0.2900	0.2900	0.2700
Priming of the pump	0.6300	0.5950	0.6300	0.6100	0.7000	0.6800	0.6000	0.6000
	0.5850	0.6100	0.6200	0.6000	0.5820	0.6810	0.6110	0.5900
	0.6000	0.5180	0.6400	0.6100	0.5920	0.6000	0.6000	0.6280
	0.6600	0.6500	0.6000	0.6300	0.6920	0.5980	0.6000	0.6800
	0.5890	0.6000	0.6100	0.7000	0.7000	0.7000	0.7000	0.7000





